KEEPING THE EDGE

Air Force Materiel Command Cold War Context (1945-1991)

Volume I:
Command Lineage, Scientific Achievement, and Major Tenant Missions

Karen J. Weitze

Developing, Fielding, and Sustaining America's Air and Space Force

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VOLUME II
Installations and Facilities

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Wright-Patterson Air Force Base, Ohio

United States Air Force
United States Department of Defense

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Dedicated to the Air Force Historical Research Agency,
Maxwell Air Force Base, Montgomery, Alabama

Its staff and its collections, and especially to

Joseph D. Caver, Chief of Circulation
Archangelo DiFante, Archivist
Ron Myers, Chief, Accessions Branch
Essie Roberts, Archives Technician
Dr. Frederick J. Shaw, Jr., Chief, Research Division

Foreword

The historic buildings that we have on our facilities reflect the history of our country and the Air Force. They represent the men and women that have served and given their lives for freedom. In an age of change, it is important what we preserve our historic buildings and districts, while maintaining their usefulness to fulfill our mission in the 21st century...

Sheila Widnall,
Secretary of the Air Force
17 April 1995

The inventory, documentation, and evaluation of Cold War properties have been an expanding cultural resource effort on Air Force Materiel Command (AFMC) bases from the late 1990s to the present. As inventories are completed for archaeological and 50-year-old architectural properties, the Cold War survey effort is fast becoming the priority. This is especially important as the military rehabilitates or demolishes older buildings to keep abreast of their expanding mission to maintain air superiority. Since Cold War era buildings make up a large part of the real property on most Department of Defense (DoD) installations, the inventory of such properties can become an enormous and costly undertaking. In direct response to this logistical challenge, the DoD, including the United States Air Force and its individual commands, has created guidance and contextual references to assist base managers in determining how to handle a potentially daunting task. *Keeping the Edge: Air Force Materiel Command Cold War Context (1945-1991)* represents the latest contribution to this effort.

Background

The push to manage Cold War resources began for all intents and purposes in 1991, when the DoD recognized that within its installations throughout the world there was a wealth of unique and irreplaceable resources representing one of the most important events since World War II. DoD cultural resource managers were operating under existing laws, regulations, and practices during the evaluation process for historic resources. The end of the Cold War coincided with the greatest organizational transformation of the Air Force since its creation in 1947. Confronted with a reduced military threat, the Air Force inactivated some distinguished commands, such as the Strategic Air Command, and established new ones. This period of transition and the recent nature of the Cold War left cultural resource managers confused as to a proper course of action, and Cold War resources were being lost as a consequence.

The Legacy Resource Management Program was established by the 1991 Defense Appropriations Act (Public Law 101-511, Section 8120) in fulfillment of the Congressional mandate to "determine how to better integrate the conservation of irreplaceable biological, cultural, and geophysical resources with the dynamic requirements of military missions." One of nine original Legacy emphases was the Cold War Task Area, which provided new challenges to base cultural resource managers with its objective to "inventory, protect, and conserve physical and literary property and relics of the Department of Defense connected with the origins and development of the Cold War."

For the first time, there was emphasis on the management of a large number of less-than-50-year-old properties, and yet there was no clear methodology on how best to accomplish the task other than the general guidance provided in National Register Bulletin 22, *Guidelines for Evaluating and Nominating Properties that Have Achieved Significance Within the Past Fifty Years* (1979).

The lack of guidance was brought to light in a 1992 memo from Mr. Gary Vest, Deputy Assistant Secretary of the Air Force (Environment, Safety, and Occupational Health), to the Air Force Civil Engineer regarding management of Cold War properties threatened by an undertaking at Vandenberg Air Force Base (AFB), California. Mr. Vest stated "Personnel...are uncertain of their requirements under the National Historic Preservation Act. ...There is no DoD or USAF-wide agreement concerning the eligibility of Cold War or Scientific and Technical assets for listing on the National Register of Historic Places. This is clearly an opportunity for the USAF to take the lead. Request you...develop a policy or programmatic agreement regarding Cold War materials."

The Air Force did take the lead. In early 1993, in direct response to Mr. Vest's challenge, Cold War Project Manager Dr. Rebecca Cameron (Historian, Air Force History Support Office) and a group of DoD cultural resource managers formulated a plan for addressing the preservation of the military's Cold War resources. They developed a two-phase approach consisting of site-specific documentation of the most significant Cold War era properties, and conducting broad national theme and context studies of the prominent military weapons systems and missions that played a primary role in the Cold War and had a major impact on the American landscape.

Two reports outlined the process, methodology, and goals of future Cold War studies. Dr. Paul Green (Cultural Resources Manager, Headquarters Air Combat Command) authored *Air Force Interim Guidance: Treatment of Cold War Historic Properties for U.S. Air Force Installations* (1993) and Dr. Cameron completed *Coming in from the Cold: Military Heritage in the Cold War* (1994). These reports opened the gate for a virtual flood of Legacy-funded national contexts in the mid- to late-1990s on subjects such as ballistic missiles, training and education programs, defense production facilities, communications and command centers, defensive radar networks, and, fighter and bomber aircraft missions.

Historic Contexts

The guidance and national contextual reports led, in turn, to what can be recognized as a third phase of the Cold War Task Area—command-specific historic contexts. The original DoD and Air Force reports provided guidance on how to treat Cold War properties, while the national contexts included the big-picture view of various programs. But base cultural resource managers still needed a tool to tie their base into the broader Cold War so that they could adequately inventory and evaluate their facilities. The command contexts filled this need. The contexts identified the command's most important contributions to the Cold War and the property types that supported these missions so that base managers could reduce the number of resources in need of inventory to a manageable size.

National Register Bulletin 15, *How to Apply the National Register Criteria for Evaluation*, describes a historic context.

> To qualify for the National Register, a property must be significant; that is, it must represent a significant part of the history, architecture, archeology, engineering, or culture of an area, and it must have the characteristics that make it a good representation of properties associated with that aspect of the past. ...The significance of a historic property can be judged and explained only when it is evaluated within its historic context. Historic contexts are those patterns, themes, or trends in history by

> which a specific occurrence, property, or site is understood and its meaning (and ultimately its significance) within prehistory or history is made clear. ...Historic contexts are historical patterns that can be identified through consideration of the history of the property and the history of the surrounding area.

The Air Force commands all followed the same general approach in their contexts by providing the national and command histories and baseline inventories of specific base properties (in some cases identifying command-specific property types). Dr. Green set the pace with the three-volume context, *A Systemic Study of Air Combat Command Cold War Material Culture* (1995-1997). Volume I is the *Historic Context and Methodology for Assessment*; Volume II includes 27 base-specific reports (such as Volume II-10, *A Baseline Inventory of Cold War Material Culture at Holloman Air Force Base*); and, Volume III concludes with *Summary Report and Final Programmatic Recommendations*.

Air Mobility Command followed in 1996 with separate volumes for the eight bases in the command (for example, *Grand Forks Air Force Base, Grand Forks, North Dakota: Inventory of Cold War Properties*). Each volume has a broad national Cold War chronology focused on infrastructure, a baseline building inventory, and preliminary National Register evaluations of Cold War properties. Finally, Air Education and Training Command (AETC) is currently completing the context for their eight bases, *Air Education and Training Command: Training the Peacemakers during the Cold War Era (1945-1991)*. AETC plans to complete Cold War property inventories and brief histories for each base in separate volumes.

AFMC Cold War Context

The command-specific contexts are very useful tools for cultural resource managers as they conduct their base-wide building inventories. When I was the Holloman AFB cultural resources manager, I used the Air Combat Command (ACC) context extensively, and it saved much time, effort, and money by providing the background information needed to complete the actual inventories. When I became the AFMC cultural resources manager in 1998, one of my first priorities was to initiate completion of a Cold War context for this command. Using the other command contexts as examples, determining the strengths and weaknesses of those reports in discussion with other command cultural resource managers and Cold War specialists, and recognizing the requirements of such a document from my personnel experience as a base manager, I established a format that would provide AFMC cultural resource managers with an easy-to-use historic context. The end result is similar to that of the other commands, except baseline inventories of specific properties were not completed.

Keeping the Edge is the final product of four years of effort to create a solid AFMC Cold War context, and I think it fulfills all expectations. The three-volume set follows the logical progression from the big picture and works down. It addresses three major goals.

1) Describe the Cold War, with an emphasis on the Air Force.
2) Define AFMC's role within the Air Force during the Cold War.
3) Characterize the contribution of each AFMC base and Air Force Plant (AFP) to the command's mission within the Air Force effort, with a focus on infrastructure that supported that mission.

Volume I, *Command Lineage, Scientific Achievement, and Major Tenant Missions*, begins with a short and concise synopsis of the Cold War from an Air Force viewpoint with many references to other reports. This section is abbreviated because the national Cold War context is well-described in many other sources, such as the first volume of the ACC context, and need not be repeated here.

Volume I also includes an in-depth discussion of the history of AFMC and its predecessors as the Air Force's research, development, testing, evaluation (RDT&E), and logistics command and the part it played in the Cold War. Interspersed throughout the discussion are references to the various bases and industrial plants and their roles in the mission, which are covered more fully in Volume II. In addition, there is discussion of bases that were once a part of AFMC's predecessors but have since moved to other commands, such as Holloman AFB (now within ACC).

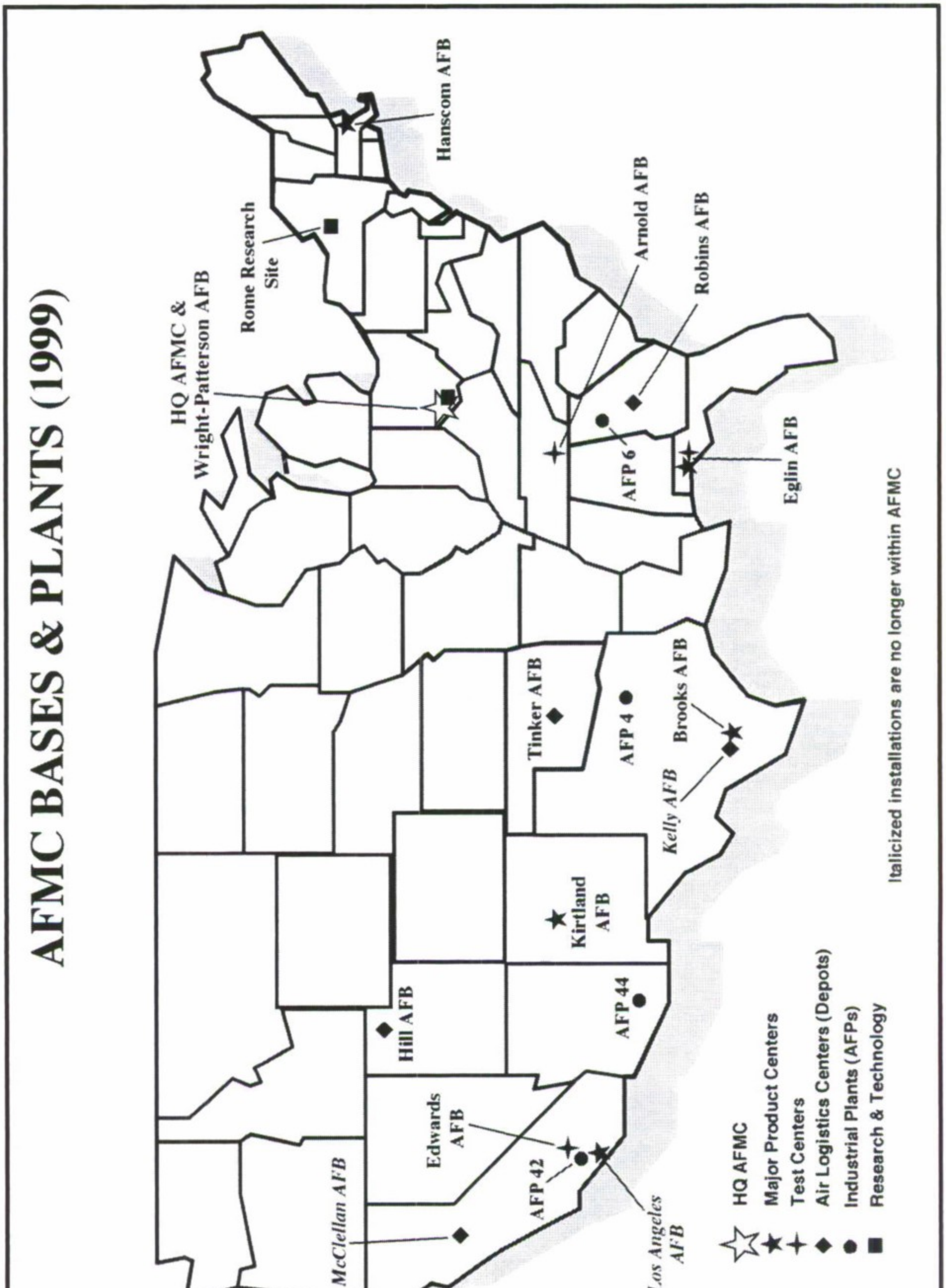
Volume II, *Installations and Facilities*, includes a chapter on each of the AFMC bases and plants. The focus is on the primary and most significant host and tenant missions accomplished at the installation during the Cold War, especially how these related to the built environment. These discussions tie in nicely with the broader Air Force and AFMC contexts in Volume I. The study includes the 14 bases and four plants within AFMC in 1999: Arnold AFB, Tennessee; Brooks and Kelly AFBs, Texas; Edwards, Los Angeles, and McClellan AFBs, California; Eglin AFB, Florida; Hanscom AFB, Massachusetts; Kirtland AFB, New Mexico; Robins AFB, Georgia; Rome Research Site (within what was Griffiss AFB), New York; Tinker AFB, Oklahoma; Wright-Patterson AFB, Ohio; and, the Air Force Industrial Plants (AFP 4, Texas; AFP 6, Georgia; AFP 42, California; and, AFP 44, Arizona) (Map). Since that time Brooks AFB has been privatized (but still maintains an AFMC mission within the Brooks City-Base); Los Angeles AFB transferred to Air Force Space Command; and, Kelly and McClellan AFBs closed. Also, there were three additional plants in AFMC in 1999 that are not included in Volume II because they were in the process of being divested to private ownership (AFP PJKS, Colorado; AFP 3, Oklahoma; and AFP 59, New York).

Volume III is a comprehensive index of the first two volumes. The amount of information within the first two volumes is extensive. It is often difficult to find specific information in reports such as these, and an index is the logical tool to make the context most useful.

The goal of *Keeping the Edge* is to provide a reference document for Cold War building inventory and evaluation projects. The first step in an inventory is a culling process to determine which buildings need intensive documentation and which can be eliminated from further consideration, since it is recognized that not all Cold War buildings can be documented prior to reaching the 50-year mark. The *Interim Guidance* provides a list of resources not considered exceptionally significant and thus ineligible for the National Register. This includes properties that would typically exist on a base regardless of the Cold War, such as family housing, base exchanges, and garages. These property types are easily identifiable because most are not directly involved in the operational mission, making the first cut relatively simple.

The *Interim Guidance* also proposes an initial set of property types and Air Force examples that meet the criteria of exceptional significance, those "operational missions and equipment of unmistakable national importance and a *direct*, not merely temporal, Cold War relationship." These include such properties as missile launch complexes, research laboratories, and radar sites. *Keeping the Edge* highlights the nationally important missions of the Cold War, AFMC, and AFMC bases and plants during that era. The base manager needs only to determine which buildings are associated with those important missions, and thus have the potential to be exceptional, and focus their initial inventories on those properties. Eligibility determinations for the properties would be based on their "unmistakable national importance" to the primary mission. Operational buildings not associated with an identified important Cold War mission can be a lower priority in the inventory schedule, or in many cases be eliminated from further consideration.

Brooks AFB provides an excellent example of the inventory process using the AFMC Cold War context and *Interim Guidance*, illustrating the priority classification and eligibility determination


AFMC BASES & PLANTS (1999)
Hanscom AFB
Rome Research Site
HQ AFMC & Wright-Patterson AFB
Arnold AFB
Robins AFB
AFP 6
Eglin AFB
Tinker AFB
AFP 4
Brooks AFB
Kelly AFB
Kirtland AFB
AFP 44
Hill AFB
Edwards AFB
AFP 42
McClellan AFB
Los Angeles AFB
HQ AFMC
Major Product Centers
Test Centers
Air Logistics Centers (Depots)
Industrial Plants (AFPs)
Research & Technology
Italicized installations are no longer within AFMC

processes. The primary Cold War mission at Brooks AFB was aeromedical research, including National Aeronautics and Space Administration-associated activities. For the Brooks Cold War inventory, only 32 of 178 buildings were directly associated with this mission. The remaining buildings were eliminated from further documentation because they only had a "temporal Cold War relationship." The 32 buildings included research laboratories, professional buildings, a library, and veterinarian support facilities associated with United States Air Force School of Aerospace Medicine (USAFSAM) (20 buildings) and the Veterinarian Science Support Colony (10 buildings), and miscellaneous support buildings (2 buildings). Only 15 of the 20 USAFSAM buildings were determined eligible for the National Register as part of a historic district. The other 17 buildings were not considered eligible because they were support buildings without exceptional functions and did not have a direct contribution to the Cold War mission at Brooks.

After identifying what *Keeping the Edge* provides for base managers, it is also important to stress what it does not provide. It is not meant to be a definitive history of AFMC, Air Force RDT&E and logistics, or of any of the bases and plants included in the study. The context is meant as a cultural resources tool that focuses on the most prominent aspects and missions of the command and the bases, and the types of infrastructure in the current real property inventory that were directly associated with those activities. There is no question that there are many other activities and missions not discussed here, and that is not an oversight. The reader must look elsewhere for more in-depth histories. If the context fulfills a researcher's need for an AFMC or RDT&E history, then that is an added bonus.

Keeping the Edge also differs from the other Air Force command contexts in that it does not provide an actual inventory or National Register evaluation of buildings, nor does it specify Cold War-era property types. This was a difficult task within AFMC because of the wide variety of missions associated with Air Force RDT&E and in many cases the activity, such as research, occurred in previously constructed infrastructure (for example, functionally specific building types were not needed). Instead, the report describes the various nationally important missions and activities and many of the buildings related to them, and identifies the bases and plants where those missions were conducted. This approach provides the base managers with the information needed to determine the infrastructure associated with the missions, and the actual inventories and National Register evaluations are accomplished at the base level where they are more accurate and complete.

Finally, there is one major dilemma faced by all commands producing Cold War contexts. The Air Force commands of today were established in 1992 during the most recent of many organizational changes that included restructuring and combining functionally similar, previously existing commands. For instance, ACC was created predominately through a merger of Strategic Air Command (SAC) and Tactical Air Command (TAC). AFMC grew out of Air Research and Development Command (ARDC) / Air Force Systems Command (AFSC) and Air Materiel Command / Air Force Logistics Command (AFLC). Throughout these reorganizations, many bases switched commands as their primary missions changed. Holloman AFB was a research and development base during the Cold War under ARDC / AFSC, which was subsumed into AFMC in 1992. Today, Holloman has an air combat mission and falls under ACC, and thus a detailed discussion of it is not included in this AFMC context. Conversely, Kirtland AFB developed and tested nuclear weapons and operated through the Cold War under the host organizations of SAC, Air Materiel Command, Special Weapons Command, ARDC / AFSC, and Military Airlift Command before ending up as an AFMC base. Kirtland is included in the AFMC, but not the ACC, context. These changes continue into the present, as Los Angeles AFB was transferred from AFMC to Air Force Space Command in 2002. Therefore, researchers must remember that the contexts define the Cold War mission of a specific command and its predecessors as illustrated by the bases of today. To get the full picture of

any command during the Cold War, one needs to review more than one context. (For example, ACC has also completed contextual studies of its predecessor commands of SAC and TAC.)

All of the command Cold War contexts have provided useful tools for the base-level managers across the Air Force and DoD. Each of the documents is different, but the end goal is the same. I feel strongly that the AFMC context brings out the best from its predecessors and is a solid example of how a context of this size can be condensed into a useable form. With the completion of *Keeping the Edge*, the Air Force now has historic contexts for most of the primary missions that, when combined, contributed to America's dominance in the Cold War: air combat (ACC); air mobility and transport (Air Mobility Command); training and education (AETC); and research, development, testing, evaluation, and logistics (AFMC).

Keeping the Edge is a success if it can be used as a reference tool by base historians and cultural resource managers. The document provides a wealth of historic research that offers a starting point for more focused work on various RDT&E and logistics missions that occurred during the Cold War in what is now AFMC—missions that contributed to America's goal of *keeping the edge* on air and space superiority. If a base cultural resource manager can use this document, along with real property records, to choose a group of exceptional Cold War buildings on the base for an inventory, and if it saves them money and time by eliminating the need for extensive background research, then it has definitely fulfilled its goal.

Martyn D. Tagg
Cultural Resources Manager
HQ AFMC/CEVQ
Wright-Patterson AFB, Ohio
May 2003

Table of Contents: All Volumes

The table of contents for the full three-volume set is included below. A boldface volume reference indicates the volume herein.

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Volume II: Installations and Facilities

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Preface

Command Lineage, Scientific Achievement, and Major Tenant Missions is Volume I of the three-volume contextual history *Keeping the Edge: Air Force Materiel Command Cold War Context (1945-1991)*. Its companion, *Installations and Facilities*, is Volume II. The third volume in the set is a stand-alone index for Volumes I and II. *Keeping the Edge* covers the 45-year period of the Cold War, from 1945 to 1989 / 1991. The study functions both as traditional military history, and as a historic context for assessing buildings and structures extant at installations reporting to Headquarters Air Force Materiel Command at the time of the study (1999-2003). In order to fulfill its role as a historic context, *Keeping the Edge* includes detailed information on the history of infrastructure and civil engineering achievements across the command. The author has highlighted key architectural-engineering firms and has endeavored to place their work for Air Force Materiel Command in perspective with other military and civilian commissions of the Cold War. *Keeping the Edge* also contains many rare photographs, most either found only at the installation level or embedded in documents housed at the Air Force Historical Research Agency at Maxwell Air Force Base in Montgomery, Alabama. The author has included as many historic photographs as possible in the study and has augmented these with contemporary images where appropriate or necessary. Research and writing for *Keeping the Edge* was a four-year effort. For the majority of the primary records, the author relied on the collections of the Air Force Historical Research Agency at Maxwell and those at the National Archives II in suburban Washington, D.C. She, or an assistant, also visited each of the installations within Air Force Materiel Command. At the bases and industrial plant sites, the history offices participated in the project, as did the cultural resource offices and civil engineering (drawings) vaults. The author assessed a wide range of buildings and structures at the bases and compared these to the information available in the records. Selected oral interviews supported the research.

Volume I, *Command Lineage, Scientific Achievement, and Major Tenant Missions*, addresses four topics:

- milestones and events of the Cold War from a joint American-Soviet perspective, including a brief analysis of key political, economic, and scientific preludes during the years leading up to the conflict;
- the complex lineage of commands and installations evolving into today's Air Force Materiel Command;
- the importance of research, development, testing, and evaluation to the command, supported through selected examples of early Cold War scientific achievement; and,
- major tenant missions on command bases.

For the latter, chosen tenant missions are each part of national high-profile programs of the Cold War. Missions include those of Air Defense Command (command posts and fighter alert), Strategic Air Command (bomber alert), missile and space tracking (large phased array radar), and varied research and development (R&D) tied to the National Advisory Committee for Aeronautics (NACA) / National Aeronautics and Space Administration (NASA).

Acknowledgments

Many individuals contributed their time and assistance to *Keeping the Edge: Air Force Materiel Command Cold War Context (1945-1991).* The author especially wants to thank the project director at Headquarters Air Force Materiel Command, Mr. Martyn D. Tagg. Other individuals at Wright-Patterson Air Force Base also sustained a high level of involvement, and were always helpful in answering the author's questions, finding requested documents and photographs, and opening doors to facilities at the installation. These men and women include Mr. John D. Weber, the command historian, as well as historians and archivists in the Headquarters Air Force Materiel Command History Office. Archivist Jean August, now retired, prepared materials in advance for the author, and generously gave her time to help locate files and documents. Drs. William Elliott and Paul C. Ferguson (formerly of the Aeronautical Systems Center History Office on base) also answered queries on more than one occasion. Other historians at Wright-Patterson who met with the author to discuss the project and to assist in finding particular kinds of information were Dr. Henry Narducci of the 88th Air Base Wing History Office; Ms. Diana G. Cornelisse, chief historian of the Aeronautical Systems Center History Office; Dr. James F. Aldridge, Ms. Lori S. Tagg, and Mr. Bruce Hess of the Aeronautical Systems Center History Office; and Mr. George W. Cully of the Air Force Research Laboratory History Office (now, of the Headquarters Air Force Materiel Command History Office). Dr. Janet E. Ferguson of the Environmental Management Office, 88th Air Base Wing, and Mr. Frank Tokarsky of the Environmental Compliance Branch of Aeronautical Systems Center also assisted the author at the base. Ms. Ferguson and Mr. Tokarsky accompanied the author on tours of buildings and structures during 1999, 2000, and 2001. Ms. Ferguson arranged for access to the civil engineering drawings storage vault, as well as provided electronic copies of particular drawings as requested. Mr. Tokarsky met the author at former Air Force Plant 85 in Columbus, Ohio, the former Gentile Depot in Dayton, and Air Force Plant 6 in Marietta, Georgia. He also provided contacts and information on other Air Force Plants. Complementing the involvement of multiple offices at Wright-Patterson is that of the Air Force Historical Research Agency at Maxwell Air Force Base in Alabama. *Keeping the Edge* would not have been possible without the continued generous support of the Agency. The author again thanks Mr. Joseph Caver, Ms. Essie Roberts, Mr. Archie DiFante, and Mr. Ron Myers. She also wishes to extend her appreciation to all other staff at the Agency, to Dr. Fred Shaw, chief of the Research Division, and to the librarians at the Air University Library.

The History Offices at each of the installations and research centers reporting to Air Force Materiel Command were equally generous with their assistance and support. The author wishes to thank historians and archivists across the bases, including Dr. David M. Hiebert and Ms. Peggy Shockley at the Arnold Engineering Development Center at Arnold Air Force Base in Tennessee; Staff Sergeant Patrick D. Longe of the 311th Human Systems Wing at Brooks Air Force Base in Texas; Drs. James O. Young and Raymond Puffer at Edwards Air Force Base in California; Ms. Vicki Jones (now retired) at Eglin Air Force Base in Florida; Dr. Thomas W. Thompson at the Air Force Research Laboratory in Rome, New York (on the former Griffiss Air Force Base); Dr. Ruth P. Liebowitz and Ms. Anita Heath at the Electronic Systems Center at Hanscom Air Force Base in Massachusetts; Mr. David R. Kendziora at the Ogden Air Logistics Center at Hill Air Force Base in Utah; Ms. Kathi R. Jones at the former San Antonio Air Logistics Center at Kelly Air Force Base in Texas (now realigned); Drs. Robert W. Duffner and Barron K. Oder, and Mr. Steve Watson, at the Air Force Research Laboratory, and, Tech Sergeant William L. Medema of the 377th Air Base Wing, at Kirtland Air Force Base in New Mexico; Dr. Harry N. Waldron and Ms. Karen B. Austin at the Space and Missile Systems Center at Los Angeles Air Force Base in California; Drs. John Lonnquest and Craig W. Luther at the former Air Logistics Center at McClellan Air Force Base in California (now closed, with Dr. Lonnquest transferred to the Army Corps of Engineers History Office at Fort Belvoir in

Virginia and Dr. Luther to the History Office at Edwards); Dr. William P. Head and Ms. Becky Wainwright at the Warner Robins Air Logistics Center at Robins Air Force Base in Georgia; and, Dr. James L. Crowder and Mr. Dan M. Schill at the Oklahoma City Air Logistics Center, and Dr. Cecil W. Trice of the 38th Engineering Installations Wing, at Tinker Air Force Base in Oklahoma.

Cultural resource managers and other environmental personnel at the Air Force Materiel Command installations were also essential to the project. These individuals made logistics arrangements for the author and her assistants, provided introductions to their counterparts in the civil engineering drawings vaults and real property records, and often accompanied the author on a tour of buildings and structures at the bases. *Keeping the Edge* benefited significantly from the efforts of these managers. The author would like to thank Mr. Clark Brandon, Mr. Mark Moran, and Mr. Martin Johnson at Arnold; Mr. Hamid Kamalpour and Mr. John D. Clark at Brooks; Mr. Richard Norwood at Edwards; Dr. Newell Wright (now retired), Mr. Russell Gunter, Mr. Mark Stanley, Ms. Tegan Swain, and Mr. David Pugh at Eglin; Mr. Mike Bamberger at the Air Force Research Laboratory in Rome, New York (at the former Griffiss); Mr. Donald C. Morris at Hanscom; Ms. Debbie Hall and Ms. Jaynie Hirschi at Hill; Mr. Richard Black and Ms. Judy Keith at Kelly; Ms. Cynthia Gooch and Ms. Christine Tuttle (now with the Navy in San Diego) at Kirtland; Mr. Dan Dickerson at Los Angeles; Mr. Carlos Payne and Mr. John Carroz at McClellan; Ms. Cheryl Hull at Robins; Mr. Tim Taylor at Tinker; and, again, Dr. Jan Ferguson at Wright-Patterson. Ms. Julia Cantrell, at the Air Force Center for Environmental Excellence (AFCEE), participated in the arrangements for Brooks.

Those individuals who assisted research efforts through access and guidance in the civil engineering drawings vaults at the installations included multiple military and civilian staff. At Arnold the author is especially appreciative of the time and assistance of Ms. Sarah Potuk, in searching the largest collection of drawings for buildings and equipment she has ever encountered. For the other installations, the author thanks Mr. George Garcia, Mr. Julio Lopez, and Ms. Patsy Marquez (Brooks); Mr. Jerry Champion, Mr. Jerry Rankin, Mr. Andrew Jesus Ortega, and Ms. Shirley Burt (Eglin); Mr. Michael Wojnas (the Air Force Base Conversion Agency at the former Griffiss); Mr. Scott Haslett (Hanscom); Ms. Jackeline Gavuardi (Hill); Mr. David Tovar (Kelly); Mr. Cecil Whitson (Kirtland); Mr. Aram Kyupelyan and Mr. Amos Jones (Los Angeles); Mr. John Thompson and Ms. Mary L. Shields (McClellan); Mr. Halverson (Tinker); and, Mr. Don R. Smith (Wright-Patterson).

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List of Acronyms

AACS	Airways and Air Communications Service
AAF	Army Air Forces
ABC	atomic, biological, and chemical
ABM	antiballistic missile
ABMA	Army Ballistic Missile Agency
ACC	Air Combat Command
ACSC	Air Command and Staff College
AC&W	Aircraft Control & Warning
AD	Air Division; Armament Division
ADC	Aerospace Defense Command; Air Defense Command
ADCC	Air Defense Control Center
ADC-H	Air Direction Center - Heavy
ADC-L	Air Direction Center - Light
ADDC	Air Defense Direction Center
ADIS	Air Defense Integrated System
ADIZ	Air Defense Identification Zone
ADSID	Air Defense Systems Integration Division
ADTC	Armament Development and Test Center
AEC	Atomic Energy Commission
AEDC	Air Engineering Development Center; Arnold Engineering Development Center
AEDD	Air Engineering Development Division
AEW&C	Airborne Early Warning and Control
AF	Air Force
AFAC	Air Force Armament Center
AFAL	Air Force Avionics Laboratory
AFAPL	Air Force Aero Propulsion Laboratory
AFATL	Air Force Armament Test Laboratory
AFB	Air Force Base
AFBMD	Air Force Ballistic Missile Division
AFC^{4}A	Air Force Command, Control, Communications, and Computers Agency
AFCC	Air Force Communications Command
AFCCDD	Air Force Command and Control Development Division
AFCE	Air Force Civil Engineer
AFCEC	Air Force Civil Engineering Center
AFCEE	Air Force Center for Environmental Excellence
AFCMD	Air Force Contract Management Division
AFCRL	Air Force Cambridge Research Laboratories
AFCS	Air Force Communications Service
AFETR	Air Force Eastern Test Range
AFFDL	Air Force Flight Dynamics Laboratory
AFFTC	Air Force Flight Test Center
AFGL	Air Force Geophysics Laboratory
AFHRL	Air Force Human Resources Laboratory
AFLC	Air Force Logistics Command
AFMC	Air Force Materiel Command
AFML	Air Force Materials Laboratory
AFMSW-1	Air Force Materiel Special Weapons-One
AFOAT	Air Force Office of Atomic Energy

AFOOA	Air Force, Deputy, Chief of Staff of Operations, the Assistant for Operations Analysis
AFOSR	Air Force Office of Scientific Research
AFP	Air Force Plant
AFPRO	Air Force Plant Representative Office
AFRD	Air Force Research Division
AFRL	Air Force Research Laboratory
AFRPL	Air Force Rocket Propulsion Laboratory
AFSC	Air Force Systems Command
AFSCF	Air Force Satellite Control Facility
AFSPC	Air Force Space Command
AFSTC	Air Force Space Technology Center
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
AFTAC	Air Force Technical Applications Center
AFWAL	Air Force Wright Aeronautical Laboratories
AFWL	Air Force Weapons Laboratory
AFWTR	Air Force Western Test Range
AG	Aktien Gesellschaft
AGARD	Advisory Group for Aeronautical Research and Development
AGD	Adjutant General Department
AGM	air-to-ground missile
AIM	air intercept missile
ALC	Air Logistics Center
ALCM	air-launched cruise missile
AMA	Air Materiel Area
AMC	Air Materiel Command
AMD	Aerospace Medical Division
AMRAAM	advanced medium range air-to-air missile
ANG	Air National Guard
ANMB	Army-Navy Munitions Board
AOAMD	Atlantic Overseas Air Materiel Division
ARAACOM	Army Antiaircraft Command
ARADCOM	Army Air Defense Command
ARDC	Air Research and Development Command
ARIA	Advanced Range Instrumentation Aircraft; Apollo Range Instrumentation Aircraft
ARL	Aerospace Research Laboratories
ARO	Arnold Research Organization
ARPA	Advanced Research Projects Agency
ASACS	Airborne Surveillance and Control System
ASC	Aeronautical Systems Center
ASD	Aeronautical Systems Division
ASTIA	Armed Services Technical Information Agency
ATC	Air Training Command
ATI	Air Technical Intelligence
ATSC	Air Technical Service Command
AVA	Aerodynamische Versuchsanstalt [Göttingen]
AW	atomic warfare
AWAC	Airborne Warning and Control
AWS	Air Weather Service; Aircraft Warning Service

BAQ	Bachelor Airmen's Quarters
BEEF	[Prime] Base Engineering Emergency Force
BIF	Basic Information Folder
BMEWS	Ballistic Missile Early Warning System
BMO	Ballistic Missile Office
BMW	Bavarian Motor Works
BRAC	Base Realignment and Closure
BUIC	Back-Up Interceptor Control
BW	biological warfare
C^3	command, control, and communications
C^4	command, control, communications, and computers
CADF	Central Air Defense Force
CBR	chemical, biological, and radiological
CC	combat center; control center
CCMR	Central Contract Management Region
CDS	Comprehensive Display System
CE	civil engineer
C-E	communications-electronics
CEBAR	chemical, biological, and radiological
CERF	Civil Engineering Research Facility
CEVC	Civil Engineer Directorate, Environmental Compliance Branch
CEVP	Civil Engineer Directorate, Environmental Analysis Branch
CIA	Central Intelligence Agency
CINCLANT	Commander-in-Chief Atlantic Fleet
CINCONAD	Commander-in-Chief CONAD
COMD	[Headquarters] Command
CONAC	Continental Air Command
CONAD	Continental Air Defense Command
CONUS	Continental United States
CRC	Cambridge Research Center
CSUSA	Chief of Staff United States Army
CW	chemical warfare
DA	Department of the Army
DC	double cantilever [hangar]; direction center
DCS	Deputy Chief of Staff
DEFCON	Defense Condition
DEW	Distant Early Warning
DMJM	Daniel, Mann, Johnson & Mendenhall
DoD	Department of Defense
DOE	Department of Energy
DTRIAC	Defense Threat Reduction Information Analysis Center
DU	depleted uranium
D&W	detection and warning
EADF	Eastern Air Defense Force
EIC	Engineering Installation Center
ENIAC	Electronic Numerical Integrator and Calculator
EOARD	European Office of Aerospace Research and Development
ESAR	Electronically Scanned Array Radar
ESD	Electronic Systems Division
ESMC	Eastern Space and Missile Center
EUCOM	European Command

EWS	Early Warning Station
FAD	Ferrite Array Radar
FASC	Fairfield Air Service Area
FATSC	Fairfield Air Technical Service Command [Area]
FEAF	Far East Air Forces
FFAR	folding fin air-to-air rocket
FIS	Fighter-Interceptor Squadron
FJSRL	Frank J. Seiler Research Laboratory
FTC	Flight Test Center
FTD	Foreign Technology Division
FY	fiscal year
G	gravitational force
GALCIT	Guggenheim Aeronautical Laboratory at the California Institute of Technology
GAM	guided air missile
GAP	Government Aircraft Plant
GAR	guided air rocket
GB	sarin gas
GCI	Ground Control Intercept
GEEIA	Ground Electronics Engineering Installation Agency
GLCM	ground-launched cruise missile
GOCO	government-owned, contractor-operated
GS	general schedule
GSA	General Services Administration
HABS	Historic American Buildings Survey
HADC	Holloman Air Development Center
HAER	Historic American Engineering Record
HB	heavy bomber
HFORL	Human Factors Operations Research Laboratories
HO	History Office
HQ	headquarters
HRRC	Human Resources Research Center
HRRI	Human Resources Research Institute
HVAR	high velocity aircraft rocket
ICBM	intercontinental ballistic missile
IDECO	International Derrick and Equipment Company
IEEE	Institute of the Electrical and Electronics Engineers
IIT	Illinois Institute of Technology
IRBM	intermediate range ballistic missile
JB	jet bomb
JFK	John F. Kennedy
JIOA	Joint Intelligence Objectives Agency
JSS	Joint Surveillance System
LFA	Luftfahrtforschungsanstalt Hermann Göring
MAAMA	Middletown Air Materiel Area
MAC	Military Aircraft Command
MAMA	Middletown Air Materiel Area
MAP	Multiple Aim Point [basing for the MX]
MASC	Middletown Air Service Area
MATS	Military Air Transport Service
MATSC	Middletown Air Technical Service Command [Area]
MB	medium bomber

MBA	Masters in Business Administration
MIATSC	Miami Air Technical Service Command [Area]
MIRV	multiple independently-targetable reentry vehicles
MIT	Massachusetts Institute of Technology
MOAMA	Mobile Air Materiel Area
MOASC	Mobile Air Service Command [Area]
MOATSC	Mobile Air Technical Service Command [Area]
MOU	Memorandum of Understanding
MPS	Multiple Protective Shelters [basing for the MX]
MSFC	Marshall Space Flight Center
MSR	Missile Site Radar
MTC	Missile Test Center
MX	missile experiment [MX Peacekeeper ICBM]
N	anthrax
NACA	National Advisory Committee for Aeronautics
NACC	NORAD Automated Control Center
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBC	nuclear, biological, and chemical
NCAR	National Center for Atmospheric Research
NCC	NORAD Control Center
NCEL	Naval Civil Engineering Laboratory
NDRC	National Defense Research Committee
NEAC	Northeast Air Command
NLO	National Lead of Ohio
NMERI	New Mexico Engineering Research Institute
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Air Defense Command
NRD	National Range Division
NRL	Naval Research Laboratory
NSC	National Security Council
NSS	National Storage Site
OAMA	Ogden Air Materiel Area
OAR	Office of Aerospace Research
OASC	Ogden Air Service Command [Area]
OATSC	Ogden Air Technical Service Command [Area]
OCAFS	Oklahoma City Air Force Station
OC-ALC	Oklahoma City Air Logistics Center
OCAMA	Oklahoma City Air Materiel Area
OCASC	Oklahoma City Air Service Command [Area]
OCATSC	Oklahoma City Air Technical Service Command [Area]
OO-ALC	Ogden Air Logistics Center
OOAMA	Ogden Air Materiel Area
OSRD	Office of Scientific Research and Development
OSS	Operational Storage Site
PAR	Perimeter Acquisition Radar
PARCS	Perimeter Acquisition Radar Attack Characterization System
PAVE PAWS	Perimeter Acquisition Vehicle Entry Phased Array Warning System
PAX	Office of Public Affairs
POAMD	Pacific Overseas Air Materiel Division
PW	prisoners of war

RADC	Rome Air Development Center
RAF	[British] Royal Air Force
RAMA	Rome Air Materiel Area
RAND	Research and Development (Douglas Aircraft)
RATSC	Rome Air Technical Service Command [Area]
RCA	Radio Corporation of America
R&D	research and development
RDC	Research and Development Command
RDT&E	research, development, testing, and evaluation
REG	Returnee Exploitation Group
RF	radiation field
RFC	Reconstruction Finance Corporation
ROAMA	Rome Air Materiel Area
ROASC	Rome Air Service Command [Area]
ROCC	[NORAD] Region Operations Control Center
RW	radiological warfare
S	secret [security classification]
SA-ALC	San Antonio Air Logistics Center
SAAMA	San Antonio Air Materiel Area
SAASC	San Antonio Air Service Command [Area]
SAATSC	San Antonio Air Technical Service Command [Area]
SAB	Scientific Advisory Board
SAC	Strategic Air Command
SAG	Scientific Advisory Group
SAGE	Semi-Automatic Ground Environment
SAGID	*unknown*
SALT	Strategic Arms Limitations Talks
SAMA	Sacramento Air Materiel Area
SAMSO	Space and Missile Systems Organization
SAMTEC	Space and Missile Test Center
SAMTO	Space and Missile Test Organization
SASC	Sacramento Air Service Command [Area]
SATSC	Sacramento Air Technical Service Command [Area]
SBAMA	San Bernardino Air Materiel Area
SBASC	San Bernardino Air Service Command [Area]
SBATSC	San Bernardino Air Technical Service Command [Area]
SCA	Southern Communications Area
SCR	Signal Corps Radio
SCS	Signal Corps [fighter control] System
SD	Space Division
SDI	Strategic Defense Initiative (Star Wars)
SEON	Solar Electro-Optical Network
SLBM	sea (submarine)-launched ballistic missile
SM-ALC	Sacramento Air Logistics Center
SMAMA	Sacramento Air Materiel Area
SOM	Skidmore, Owings & Merrill
SPACERAD	Space Radiation Effects
SPADATS	Space Detection and Tracking System
SPAMA	Spokane Air Materiel Area
SPASC	Spokane Air Service Command [Area]
SPATSC	Spokane Air Technical Service Command [Area]

SRAM	short range attack missile
SRI	Stanford Research Institute
START	Strategic Arms Reduction Treaty
Strat-X	strategic missile
TAC	Tactical Air Command
TDY	Temporary Duty Station
TOW	tube-launched, optically-tracked, wire-guided [missile]
TR	technical report
T/R	transmitter/receiver
TRACE	Transportable Automated Control Environment
TVA	Tennessee Valley Authority
TWA	TransWorld Airlines
URSAM	Max O. Urban, Roberts & Schaefer, Seelye, Stevenson, Value & Knecht and Moran, Proctor, Muser & Rutledge
USACERL	United States Army Construction Engineering Research Laboratories
USAF	United States Air Force
USAFE	United States Air Forces in Europe
USAFSAM	United States Air Force School of Aerospace Medicine
USAFSS	United States Air Force Security Service
USG	Uncle Slant George [underground aircraft plant project]
USSR	Union of the Soviet Socialist Republics
UTTR	Utah Test and Training Range
V	Vergeltung or Vereinigung
VE	Victory in Europe
VHB	very heavy bomber [alternately, the B-29 and the B-36]
VHF	very high frequency
VJ	Victory in Japan
VVHB	very very heavy bomber [the B-36]
WAAC	Women's Auxiliary Army Corps
WACS	White Alice Communications System
WADC	Wright Air Development Center
WADD	Wright Air Development Division
WADF	Western Air Defense Force
WAI	Weidlinger Associates, Incorporated
WDD	Western Development Division
WISE	World-Wide Installation of Supply Economy
WPAFB	Wright-Patterson Air Force Base
WR-ALC	Warner Robins Air Logistics Center
WRAMA	Warner Robins Air Materiel Area
WRASC	Warner Robins Air Service Command [Area]
WRATSC	Warner Robins Air Technical Service Command [Area]
WRS	Weather Reconnaissance Squadron
WSMC	Western Space and Missile Center
WSPO	Weapons Systems Project Office
XB	experimental bomber
XD	experiment digital(?)
Z-D	Zeiss-Dywidag

Introduction

Keeping the Edge: Air Force Materiel Command Cold War Context (1945-1991) is a three-volume document that offers a 45-year historic context for the installations that fall under the umbrella of today's Air Force Materiel Command (AFMC).

Volume I, *Command Lineage, Scientific Achievement, and Major Tenant Missions*, is set up in four sections.

- Part I of Volume I provides a broad context for the command's role in the Cold War. The section discusses American and Soviet political, economic, and scientific benchmarks of the early-to-middle 20th century that set the stage for the conflict. Part I of Volume I defines the Cold War as beginning during 1944-1945, and ending through a series of symbolic events that occur over the period of 1989 to 1991. The remainder of the overview divides the Cold War into four periods

    1. the early Cold War, 1945-1954
    2. the middle buildup years, 1955-1962
    3. the plateau of international awareness and counterinsurgency wars on third-party soils, 1963-1975
    4. the joint American-Soviet escalation leading to the war's end, 1976-1991

    and briefly references three companion contextual histories for Headquarters Air Combat Command (Lewis, Roxlau, Rhodes, Boyer, and Murphey: 1995-1997), Headquarters Air Mobility Command (Weitze: 1996), and Headquarters Air Education and Training Command (Prior and Salo: draft, 2002). A chronology of key milestones follows, adapted from *Coming in from the Cold: Military Heritage in the Cold War* (Cameron: 1993), *The Cold War and Beyond: Chronology of the United States Air Force, 1947-1997* (Shaw and Warnock: 1997), and past studies by the author. The bibliography includes all sources of information for the Cold War timeline, although most included events are public knowledge. Part I of Volume I organizes the timeline by year, with entries for each year of the 1945-1991 timeframe. To highlight the international character of the war, references to countries with ties to the United States and the Soviet Union appear in boldface type.

- Part II of Volume I details the lineage of the command. This section briefly summarizes the command's Cold War antecedents, before turning to a close look at the two halves of what would evolve into AFMC. Part II of Volume I traces the lineage of Army Air Forces and Air Force research and development (R&D) from 1945 through 1989-1991, and in a parallel manner delineates the Cold War history of the broad logistics mission within the command's forbearers. Part II explores the lineage of Air Technical Services Command, Air Materiel Command, Air Research and Development Command (ARDC) / Air Materiel Command, and Air Force Systems Command (AFSC) / Air Force Logistics Command (AFLC), including the evolution of R&D centers and depots throughout the continental United States. Tied to the latter, Part II also addresses the role, number, and type of Air Force industrial plants that supported the logistics mission. As used herein, R&D encompasses the full breadth of the research, development, testing, and evaluation mission.

    The Army Air Forces (and early Air Force) R&D and logistics missions entered the Cold War period together, within Air Technical Service Command (1945-1946) and Air Materiel Command (1946-1950) headquartered at Wright Field (Wright-Patterson Air Force Base) in

Ohio. During 1949 and 1950, the Air Force formally reviewed its organization of R&D, critical to the unfolding of both the fledgling Air Force and the escalating Cold War. Following the efforts and recommendations of the Ridenour Committee, Headquarters Air Force moved to separate the R&D mission from that of logistics. In 1951, Air Materiel Command split into two commands, those of ARDC and Air Materiel Command. ARDC thereafter was responsible for the R&D mission, while Air Materiel Command oversaw the logistics mission. During the 1950s, the installations subsumed under ARDC and Air Materiel Command developed quite differently from one another, although the missions of the two commands remained linked. The gray areas between such endeavors as experimental and production engineering, for example, demanded that ARDC and Air Materiel Command would sustain many overlapping roles for the Air Force. The Air Force Bases at which ARDC was host or tenant developed as R&D mission-specific centers tiered beneath Headquarters ARDC in Baltimore (and later, at Andrews Air Force Base in Washington, D.C.). Those installations reporting to Headquarters Air Materiel Command were depots, responsible for production, modification, storage, and supply across the Air Force. Each of these installations managed a geographic area within the continental United States and / or overseas. Air Materiel Command's headquarters remained at Wright-Patterson, maintaining its location there unbroken from its origins during the early 20th century. In 1961, ARDC and Air Materiel Command underwent name changes to AFSC and AFLC. Headquarters AFSC continued at Andrews, with several key functions located nearby at Bolling Air Force Base to accommodate the unwieldy R&D missions of both the command and Headquarters Air Force. Headquarters AFLC stayed at Wright-Patterson. Shortly after the end of the Cold War, Headquarters Air Force reunited AFSC and AFLC as a single command, AFMC, with its headquarters again rejoined as a single entity at Wright-Patterson.

- Part III of Volume I describes the rise of Air Force science, applied engineering, and new technologies as the Cold War unfolded. The central role of science in the winning of the Cold War is common knowledge, yet its orchestration within the Air Force—and principally within ARDC / AFSC—is complex, tied to the intertwined missions of specific R&D centers reporting to Headquarters ARDC / AFSC and to ancillary research sites operated by both corporations and universities. The section begins with an overview discussion of Army Air Forces and Air Force interpretations of the future air materiel mission. The government published these "theories of the future" sequentially as *Where We Stand* (August 1945), the 13-volume *Toward New Horizons* (December 1945), *The Woods Hole Summer Study* (1957-1958), the 25-volume *Project Forecast* (1964), *Toward New Horizons II* (1975), and *Forecast II* (1986). Written by leaders in many scientific fields, the studies made sweeping, yet detailed, assessments of future aeronautical R&D.

  Following this summary, Part III of Volume I examines the impact of Project Paperclip and its successive recruitments of the early and middle 1950s. Paperclip brought hundreds of German scientists and engineers to the United States, principally to work within the R&D structure of the Air Force, Army, and Navy, but also placed in offices and test laboratories of numerous critical military-industrial contractors. Paperclippers made substantial contributions to ARDC during the 1950s in particular, with large contingents at Wright-Patterson and at Holloman Air Force Base in New Mexico. Smaller clusters of Paperclip men and women also worked at other R&D centers subsumed within Air Materiel Command and ARDC—most notably at the Watson Laboratories in New Jersey, the Cambridge Research Laboratories (Center) at Hanscom Air Force Base in Massachusetts, and the Arnold Engineering Development Center (AEDC) in Tennessee. At Brooks Air Force Base in San Antonio, a small group of Paperclippers participated in important aerospace medical

advancements under AFSC, following upon the work of a sizeable group of Paperclippers at Randolph Air Force Base under Air Training Command. (Aviation medicine at Randolph and Brooks was also linked to work occurring concurrently in the aeromedical laboratory at Wright-Patterson.) While the Paperclippers were by no means the only scientists and engineers within ARDC / AFSC that made significant contributions to Air Force R&D, they represented a unique post-World War II phenomenon that had a lasting effect—addressed here to illustrate some of the subtleties of the earliest Cold War years.

Finally, Part III of Volume I explores a few "special missions" within Air Materiel Command and ARDC, as evocative of Air Force Cold War R&D. Generally, these missions are pertinent to the early Cold War period of the late 1940s through the 1950s, again to help a reading audience grasp the truly remarkable achievements of Air Force science and engineering in the new era. Examples are not intended to be comprehensive, and include: the biochemical and nuclear problem sets; sophisticated civil engineering; and, the Air Force science laboratory. In the case of the second example, Part III looks at an underground pilot project; the design of control and direction centers by Air Materiel Command for Air Defense Command (ADC); and, the special studies office and structures division at Wright-Patterson and Kirtland Air Force Bases, respectively. These three examples all reflect the importance of protective (and, ultimately, hardened) structures, linked to the successive improvements in biological, chemical, and nuclear weapons. The last example, a discussion of ARDC clusters of science laboratories, focuses on the collegiate-planned groups at Hanscom and illustrates that the command consciously patterned the physical layout and design of its laboratories to be identical to university and corporate R&D centers of the 1945-1955 period.

- Part IV of Volume I looks at selected major tenant missions sustained for long periods at multiple ARDC / AFSC and Air Materiel Command / AFLC installations. While other tenant missions certainly existed on ARDC / AFSC and Air Materiel Command / AFLC bases, the ones reviewed here all had a critical national role and generated a physical landscape of buildings and structures.

  The first example is that of sequential generations of air defense command and control. ARDC and Air Materiel Command installations hosted five of the 16 total Air Defense Control Centers (ADCCs) of the late 1940s and early 1950s, also hosting an Air Defense Direction Center (ADDC): at Griffiss (New York), Kirtland (New Mexico), Norton (California), Tinker (Oklahoma), and Wright-Patterson Air Force Bases. Additionally, the Lincoln Laboratory at Hanscom Air Force Base was important in the experimental ADCC / ADDC program, with an off-site control center at North Truro, Massachusetts. As of the middle 1950s, Hanscom became the site of the Experimental Semi-Automatic Ground Environment (SAGE) control center, with a SAGE Combat Center and Direction Center built at Hancock Field, a subinstallation of Griffiss. AFSC and AFLC sustained one Back-Up Interceptor Control (BUIC) command post during the early 1960s (at Tinker), and a Region Operations Control Center (ROCC) for the Joint Surveillance System (JSS) in the middle 1980s (at Griffiss). The latter was one of four ROCCs in the continental United States. To give the reader a better understanding of air defense command and control throughout the Cold War, the discussion provides an overview of the development of air defense control centers, from the Fighter Control Center of late World War II, through the ADCC / ADDC program, SAGE, BUIC, and the JSS. The section concludes with a look at the individual command posts on ARDC / AFSC and Air Materiel Command / AFLC bases. For Tinker, Part IV gives a more detailed history, due to the truly unusual role that its combined ADCC and ADDC played in the Cuban missile crisis of 1962.

The second example is that of fighter alert, a mission directly tied to air defense command and control. (Both missions were the responsibility of ADC.) Men and women stationed in the generations of command posts scrambled fighter aircraft kept on alert at area airfields. Fighter aircraft responded to possible threats, participated in war games, and ferried Soviet aircraft down the American coasts. Fighter alert also created a distinct physical landscape of alert aprons and hangars, ready maintenance hangars, aircraft shelters, ready crew quarters, squadron operations, calibration sheds, and generations of weapons storage. Across ARDC / AFSC and Air Materiel Command / AFLC, Griffiss, Hanscom, Kirtland, and Wright-Patterson sustained fighter alert missions beginning in the early 1950s, while Edwards (California) and Eglin (Florida) each supported fighter alert during the early 1960s and early 1970s, respectively.

Bomber alert, for Strategic Air Command (SAC), is the third example of a widespread tenant mission found across ARDC / AFSC and Air Materiel Command / AFLC installations. Bomber alert occurred in two very distinct eras, first as of the late 1950s, and again as satellite alert during the middle 1970s. SAC alert of the 1950s and 1960s generated a landscape of secured alert compounds at 65 bases, compounds that included herringbone alert aprons (Christmas trees) in varying sizes, alert crew quarters (moleholes), maintenance and fuel systems nose docks (bracketing a separate maintenance apron), operations buildings, and, in some cases run-up and service shops for the Hound Dog / Quail weapons package. SAC alert of this era was present at Eglin, Griffiss, Robins (Georgia), and Wright-Patterson. Hill Air Force Base in Utah briefly sustained satellite alert of the later period, relying on the herringbone alert apron and prefabricated, modular crew quarters and operations units. Again, included discussion offers the reader a broader context for understanding SAC alert at ARDC / AFSC and Air Materiel Command / AFLC bases, looking at how the SAC mission at Eglin, Griffiss, Hill, Robins, and Wright-Patterson compares with alert nationwide.

The fourth example of a major tenant mission found on ARDC / AFSC and Air Materiel Command / AFLC installations is that of large phased-array radar tracking, for sea (submarine)-launched ballistic missiles (SLBMs) and space objects. At Eglin, the Rome Air Development Center (RADC)—an R&D center within ARDC / AFSC—supervised the design of the first large phased-array radar in the world. At Robins, the base hosted the fourth Perimeter Acquisition Vehicle Entry Phased-Array Warning System (PAVE PAWS) in the middle 1980s. These radars were two among the 10 erected for the Air Force and Army during the 1960-2000 period (excluding the test radars on the Kwajalein Atoll). Throughout the buildout of large phased-array radars, both the RADC and Electronic Systems Division at Hanscom filled major roles in technical oversight and project management.

The final example provided in Part IV of Volume I offers an introductory analysis of the intertwined aerospace missions of ARDC / AFSC and the National Advisory Committee for Aeronautics (NACA) / National Aeronautics and Space Administration (NASA). Examples of key NACA / NASA-related missions (and / or presence) existed at Brooks, Edwards, Eglin, Griffiss (the RADC), Hanscom, and Wright-Patterson.

Volume II, *Installations and Facilities*, looks at each of today's installations. Individual chapters provide a summary history, base by base.

Installations included are:

- Arnold (the AEDC);
- Brooks (the Aerospace Medical Center);

- Edwards (the Air Force Flight Test Center);
- Eglin (the Armament Center);
- Hanscom (the Cambridge Laboratories [Center] / Electronics Systems Division [Center]);
- Hill (a depot base);
- Kelly (a depot base);
- Kirtland (the Air Force Special Weapons Center / Air Force Weapons Laboratory);
- Los Angeles (aerospace and missiles systems R&D);
- McClellan (a depot base);
- Robins (a depot base);
- the Air Force Research Laboratory in Rome, New York (the RADC);
- Tinker (a depot base); and,
- Wright-Patterson (a very early depot base, subsequently Headquarters for Air Materiel Command / AFLC; and, host for the Wright Air Development Center, the Wright Air Development Division, the Aeronautical Systems Division, and the Aeronautical Systems Center).

The concluding chapter treats the four existing Air Force industrial plants located at Fort Worth, Texas; Marietta, Georgia; Palmdale, California; and, Tucson, Arizona. Aeronautical Systems Center at Wright-Patterson oversees these facilities.

These installation-focused looks at ARDC / AFSC and Air Materiel Command / AFLC are necessarily concise, and do not attempt to encapsulate the full breadth and depth of Cold War Air Force missions at the bases. The chapter histories try to relate missions to infrastructure, an unusual perspective for military history, and one intended to bring history alive in the buildings and structures that remain on the Air Force landscape. Not included in Volume II are Holloman, Patrick (Florida), and Vandenberg (California) Air Force Bases, each of which had long ties to ARDC / AFSC but were not AFMC bases at the time of this study. The installations of Holloman and Patrick were particularly important within ARDC / AFSC as missile-development and missile-test centers. Discussions in Volume I include many references to activities at these installations. Also not included in Volume II are depot bases removed from Air Materiel Command / AFLC before the end of the Cold War. These installations are Brookley (Alabama), Fairchild (Washington), Olmsted (Pennsylvania), and Norton. Again, discussion for these bases is included in Volume I. Today, several bases of major importance within ARDC / AFSC and Air Materiel Command / AFLC have closed or transferred fully or partially to another host command. Of those treated in individual chapters of Volume II, Griffiss, Kelly (Texas), Los Angeles (California), and McClellan (California) fall into this category. Griffiss was in the process of becoming a business park when this study began, but still sustains the follow-on to the RADC (one of the multi-base laboratory clusters within today's Air Force Research Laboratory). Los Angeles Air Force Base is now under Air Force Space Command (AFSPC). Kelly is partly subsumed under Air Education and Training Command within the expanded boundaries of neighboring Lackland Air Force Base, with the remainder of the installation transferring to the City of San Antonio. McClellan closed while the study was underway.

<u>Volume III</u> is an index for Volumes I and II, organized and detailed to accommodate cross-referencing of the layers of information found in *Keeping the Edge*.

Goals of the Study

The three-volume history presented herein is ambitious. Such an undertaking will necessarily treat topics unevenly, and cannot hope to satisfy all possible research perspectives. *Keeping the Edge* is a *historic context*, a specific type of history written to support an understanding of buildings and

structures from a distinct time period. The context offered through this history addresses the 45-year timeframe of the Cold War and attempts to articulate a selection of the events, accomplishments, and occurrences that define the commands that evolved into today's Air Force Materiel Command. As a contextual history, *Keeping the Edge* looks most closely at history that is reflected through the built landscape and as such is tied to historic preservation goals mandated through the National Historic Preservation Act. This focus sets the study apart from traditional military histories and chronologies. To support an analysis of Air Force buildings and structures important to Air Force R&D and the logistics missions, the study also attempts to identify the major architectural-engineering firms working for ARDC / AFSC and Air Materiel Command / AFLC during the Cold War. The firms discussed here all sustained a national profile for a prolonged period. Often the lineage of architectural-engineering responsibility is difficult to trace for Air Force buildings and structures, and in this regard much rare information is given in this study. On numerous occasions, a local or regional architectural-engineering firm handled the design for another firm (thus obscuring who really did what and why), or the Army Corps of Engineers credited itself with design responsibility (when in fact the Corps' role was managerial). *Keeping the Edge* gives readers a breadth of perspective for the related commissions of particular firms, and offers encapsulated firm biographies in the chapters of Volume II. While the history presented herein is also not a traditional architectural-engineering history, the volumes do attempt to provide sufficient analysis and detail to encourage further work in this field. Finally, *Keeping the Edge* mentions many specific buildings and structures (particularly in Volume II) in support of thematic contextual discussions. Also included are numbers of very rare historic photographs, illustrating the landscape at ARDC / AFSC and Air Materiel Command / AFLC bases before the inevitable changes and alterations over time. The references to specific buildings and structures, however, should not allow this study to substitute for inventories of historic buildings at individual bases. In short, while *Keeping the Edge* cannot be all things to all people, the author hopes that the detail offered here will encourage continued Air Force and architectural-engineering history, and support cultural resource inventories as appropriate.

Methodology

The author undertook about 18 months of research for the study, followed by another two years of writing and extended editing. She relied on the collections at the Air Force Historical Research Agency at Maxwell Air Force Base in Montgomery, Alabama, and made repeated trips to the repository. The research included access to classified documents, with multiple materials excerpted for declassification and discussion (as appropriate) in the final history. The author visited nearly all of the Air Force Materiel Command installations in person. At a few installations, historians Diane Williams and Christy Dolan supported her. In most instances, the collections at base history offices augmented materials reviewed at the Historical Research Agency, providing files, documents, and photographs unique at the installation level. The community of historians within Air Force Materiel Command is particularly strong, and the author is deeply appreciative of their support for this study. Without their knowledge and years of efforts, *Keeping the Edge* would be a lesser work. While at the bases, the author also physically analyzed a large number of buildings and structures, assessing them against discussions found in the written record and conducting selected informal interviews. In support of this effort, the author read all cultural resource inventories and past studies done at the base level, including these in the bibliography. To encourage a high level of identification for architectural-engineering firms across the command, the author additionally spent many hours in the civil engineering vaults at all installations she visited. Only at Brooks, Kelly, and Los Angeles did she not do this personally—and at these installations, she directed Ms. Williams and Ms. Dolan in their searches. At Headquarters Air Force Materiel Command at Wright-Patterson, the author attempted to meet with each of the history offices. The command history office, as well as that for Aeronautical Systems Center and the 88th Air Base Wing, were especially helpful. *Keeping the Edge* follows upon a decade of Air Force research by the author, with previous analyses for Headquarters

Air Mobility Command and Headquarters Air Combat Command. In writing this study, the author drew upon her cumulative work to date. Part and chapter endnotes provide detailed references to all sources, shortened only when the discussion draws upon earlier documents written by the author (wherein, additional detailed notes exist). A reference-cited bibliography complements the endnotes, with source locations given. Project notes, including selected document excerpts, drawings, and photographs, will be archived at Headquarters AFMC. Any errors that remain in *Keeping the Edge* are the fault of the author alone, although it is her hope that these are few.

Part I: The Cold War, Milestones and Major Events

As understood through the historical perspective of the past half century, the Cold War was underway even before World War II ended in the autumn of 1945. The precise beginning of the Cold War is undetermined, subject to varied interpretations. Even the questions of who initiated the Cold War, through what specific events, are at once imprecise and without complete answers. In part, the Cold War occurred due to major scientific advances. These advances focused on the power unleashed through nuclear physics, sophisticated mathematics, and computer technology. Together they marked a point in time where human culture shifted and balances of power between nation states tipped. Political and economic world realities reinforced the scientific advances that stimulated the Cold War. Some actions and reactions moved the world stage toward a *cold war* with the cadence of inevitability. Within the American military structure, the evolution of powered flight—of aircraft and airborne devices as weapons—paralleled the unfolding achievements in physics and high-speed machine calculations. Just as the Cold War was formally named in 1947, the Army Air Forces transitioned into today's United States Air Force. And within the Air Force, the commands that would house the research and production logistics that the Department of Defense required to fight the Cold War were those that are reintegrated today as Air Force Materiel Command. Thought of another way, the scientific potential unleashed through modern era research and development (R&D) was a primary factor in the Cold War. Staying abreast of achievements at the forefront of that potential allowed the United States to keep the edge in the long war, and ultimately, to dominate in the conflict with the Soviet Union. In a directly parallel sense, R&D (and the production of aircraft, weapons systems, and support equipment that followed from it) was also central to the predecessors of Air Force Materiel Command: Air Materiel Command during the late 1940s; Air Research and Development Command (ARDC) and Air Materiel Command during the 1950s; and, Air Force Systems Command (AFSC) and Air Force Logistics Command (AFLC) from 1961 through the end of the Cold War.

Prelude to a Cold War

Noteworthy political, economic, and scientific events of the 1917 to 1939 years contributed to the Cold War of the middle 1940s forward. While the characterization below offers an oversimplified encapsulation of the period, the bulleted benchmarks provide a frame of reference for understanding the cascading of milestones that followed as of about 1944-1945. The Cold War between the United States and the Soviet Union would not have occurred as it did without the juxtaposed experiences of both countries. These experiences were sometimes nearly black and white opposites of one another, and at other times were direct echoes. In the arena of scientific achievement, the sophisticated advances by the United States and Britain toward an understanding of nuclear energy were juxtaposed by parallel early and continuous Soviet strides in the field of physics. While the United States unequivocally attained the edge with its possession of the atomic bomb in 1945, the Soviet Union stridently set about the task of catching up.

Political Benchmarks

The American point of view:

- The United States enters World War I, 1917-1918.
- The country isolates itself from European and Eurasian affairs between the wars.
- Japan's attack on Pearl Harbor on 7 December 1941 stimulates immediate entry into World War II.
- By late 1944, the war is going toward the Allies and development of an atomic bomb is approaching an actuality. The United States understands that it will have not only the major

economic position in the post-war world, but also could be in a completely unique position of atomic weapons superiority, thus allowing it to shape the world stage.

The Soviet point of view:

- Russia enters World War l, 1914-1918.
- The February 1917 Bolshevik Revolution, led by Vladimir Lenin (1870-1924) sweeps the Tsarist autocracy from power in Russia and initiates the Communist state.
- Russia signs the punitive Treaty of Brest-Litovsk with the Central Powers in March 1918. The separate peace ending World War I for Russia comes at high cost and is replaced through the general Armistice in November 1918.
- A civil war within Russia follows, and a war with Poland occupies the country.
- The Treaty of Riga with Poland reduces the size of Russia temporarily, with several countries at its borders declaring independence and functioning as a buffer area between the Communist state and Western Europe.
- The Union of the Soviet Socialist Republics (USSR / Soviet Union) begins a tentative geopolitical expansion in 1922.
- Germany officially recognizes the Soviet Union as of this year, with most European countries acknowledging the Communist state in 1924.
- Widespread hardship characterizes Germany and Russia during the 1920s, including devastating epidemics in Russia early in the decade.
- The reign of Josef Stalin (1879-1953) solidifies by 1929, after divisive struggles following Lenin's death in 1924 (marked by the October Revolution and focused on competition with Leon Trotsky [1879-1940]).
- Hitler rises rapidly to power in Germany during the early 1930s.
- America officially recognizes the Soviet Union in 1933.
- The Soviet Union becomes a member of the League of Nations in 1934.
- Repeated purges occur in the Soviet Union during the 1930s.
- The Soviet Union signs a nonaggression pact with Germany in 1939.
- A winter war between the Soviet Union and Finland takes place in 1939-1940.
- Germany attacks the Soviet Union on the morning of 22 June 1941, marking the entry of the Soviet Union into World War II.
- The Soviet Union successfully beats back Germany in the battle of Stalingrad in early 1943.
- Stalin desires to expand Soviet territorial borders, a process fundamental to the Soviet concept of power and security.
- The Soviet Union participates in the three-power conferences at Tehran (November-December 1943), Yalta (February 1945), and Potsdam (July-August 1945). The country's role evolves unequally with those of Britain and the United States. The Allies in the West tentatively begin aligning themselves in an adversarial position against their wartime partner the Soviet Union in the East. Roosevelt's handling of the American position at Yalta is sometimes interpreted as directly leading to the fall of Eastern Europe to Communism during the early Cold War.
- Soviet advances in territorial Eastern Europe following the surrender of Germany contribute to American positioning, while American behavior in Japan deeply aggravates the Soviet Union. A quick end to the war in Japan works against Soviet strategic interests in the area.

During the 20+ years between the First and Second World Wars, the United States and the Soviet Union sustain almost entirely opposite experiences of upheaval and change. The two wars are partially fought on Soviet soil, with major losses of life and imposed hardship. No fighting occurs on American land. The Soviet Union also undergoes a change in its governance equivalent to the

American Revolution of the late 18th century, while in the United States the mechanisms of democracy are largely stable—a condition accentuated by the turn away from an involvement in foreign affairs after World War I.

Economic Benchmarks

The American point of view:

- An upsurge in prosperity occurs during the 1920s, partially built upon the outcome of World War I (the Roaring Twenties).
- The stock market in New York collapses in October 1929.
- A widespread Depression ensues during the 1930s, deepening as the decade progresses and affecting the whole of American society.

The Soviet point of view:

- The Soviet Union establishes the New Economic Policy of 1921-1928, defined as an economic reconstruction of the country following upon transitional wartime efforts under Lenin.
- The first Five-Year Plan, 1928-1932, goes into effect, with major Soviet importation of foreign (including American) machinery and equipment.
- The second Five-Year Plan, 1933-1937, follows, with a turn away from foreign technology and an attempt toward self-sufficiency and economic independence.
- Widespread deprivation and repression occurs among the Soviet populace throughout the 1920s and 1930s.

For both the United States and the Soviet Union, the decade of the 1930s is one of major economic distress, with growing apprehension in both countries as Germany remilitarizes.

Scientific Benchmarks

The American point of view:

- British science stimulates American physicists simultaneously with its effect in the Soviet Union. British physicist Ernest Rutherford had postulated the idea that the atom had a nucleus in 1911, and succeeded in altering nuclei artificially in 1919.
- In 1932, James Chadwick at the Cavendish Laboratory at Cambridge discovers the neutron, while two other scientists at the facility split a lithium nucleus into two alpha particles.
- The same year, American physicists make prominent achievements. Ernest O. Lawrence at the University of California in Berkeley uses the cyclotron (which he had invented) to accelerate protons to a benchmark energy level. Carl Anderson at the California Institute of Technology in Southern California identifies the positron (the positive electron) and Harold Urey at Columbia University in New York discovers deuterium.
- In 1933, Hungarian physicist Leo Szilard moves to England to escape Nazi prosecution, reestablishing himself in New York before the end of the decade.
- During the 1930s, other major work on nuclear fission goes forward in Italy under Enrico Fermi and in Denmark under Niels Bohr. Both Fermi and Bohr flee Fascism. Fermi arrives in New York in 1939, while Bohr escapes to England in September 1943.

- Szilard becomes keenly aware of the potential of fission, and is concerned about Germany's possible pursuit of an atomic bomb project. Szilard, through Albert Einstein, voices his fears to President Roosevelt in August 1939.
- In October 1939, Roosevelt establishes a Committee on Uranium.
- In March 1940, a breakthrough paper by two scientists at the University of Birmingham in England prompts the British government to study the possibility of an atomic bomb (the Maud Committee).
- At the outset of May 1940, William Laurence, the science correspondent for the *New York Times* writes a front-page story that chronicles efforts toward atomic energy.
- Shortly after mid-1940, the primary American scientific journals and the leading physicists all accept voluntary restrictions on the publication of articles and papers discussing fission.
- The Maud Committee completes its report in July 1941, concluding that a powerful atomic bomb is feasible before the end of World War II. By September, Winston Churchill decides to pursue a bomb with all speed.
- The Maud Committee also influences American efforts toward increased nuclear research.
- Initially the Americans propose joint research with scientists in England, who decide to keep their lead to themselves. As a result, American physicists accelerate their efforts and pass their British colleagues.
- At this stage, the Americans also keep the newest research restricted, until American and British work merges. The United States invites British scientists to the United States to participate in the development of the atomic bomb.
- President Roosevelt formally authorizes the American bomb effort as the Manhattan Project in June 1942.
- Fermi achieves a self-sustaining chain reaction in a uranium-graphic pile at the University of Chicago in December 1942.
- In mid-1944, Bohr attempts to convince Roosevelt and Churchill to formally inform the Soviet Union about the Manhattan Project, feeling that this is imperative before the reality of a bomb or the end of the war.
- Roosevelt and Churchill agree in secret not to inform the Soviet Union. Bohr's fear, and that of selected others, is that the Soviet Union will interpret the lack of shared information among the three Allies as conspiring against the Communist state.
- In another instance of setting American and British interests apart from those of the Soviet Union—that is, looking beyond the end of World War II to the balance of power in the post-war period—the United States and England begin dividing the spoils of war unevenly as of spring 1945.
- This situation applies to the manipulation of the German scientists and their equipment, and in March 1945, the United States Army Air Forces deliberately bombs the Auer Company plant in Oranienburg, north of Berlin, at the request of the Manhattan Project. The plant had manufactured thorium and uranium metals for the German atomic project.
- In April 1945, a British-American group removes 1,200 tons of uranium ore from storage in a salt mine near Stassfurt, a location scheduled to fall into Soviet hands.
- On 16 July 1945, the Americans successfully drop the first test atomic bomb, code-named Trinity, on the Alamogordo Bombing and Gunnery Range in New Mexico. By this date, the Soviet Union and the United States are already on opposite sides of what would be a cold war.

The Soviet point of view:

- The Bolshevik revolution positions *science* as central to Marxism, with Marxism itself interpreted as scientific theory. Science and technology are integral to a *scientific socialism.*

- Russian physicists begin serious work on radioactivity as of the revolution.
- The Second Party Program of 1919 formally elevates the position of scientists and their families in Soviet society.
- World War 1 encourages new, close ties between science and industry, and witnesses the Communist founding of major research institutes.
- During the 1920s, Soviet physicists forge strong relations with foreign colleagues, traveling to Western Europe to obtain scientific equipment and literature.
- Soviet response to Western achievements in nuclear physics of 1932 is immediate, with a decision to build a cyclotron at the Radium Institute (not operational until late 1940) and with the hosting of an international conference on the atomic nucleus.
- By the middle 1930s, the Soviet Union is acknowledged as spending an equivalent or greater proportion of its national income on R&D than the United States, with Soviet physicists in high regard internationally.
- Simultaneously, Stalin's government sharply restricts Soviet scientists' contacts and exchanges with their foreign counterparts, with a purge of 1937-1938 badly affecting the Soviet physics community.
- By early 1939, Western scientific achievements reach Soviet scientists via journals rather than direct exchange, including the publication in *Nature* of Niels Bohr's discovery of fission. Nonetheless, Soviet scientists continue major research along the same path, absorbing what is published and making rapid successive discoveries.
- During 1939-1941, important Soviet theoretical work on the necessary conditions for a nuclear chain reaction occur, work that foreshadows the development of Soviet nuclear weapons.
- Unlike scientists in the West, including in Germany, those in the Soviet Union do not alert the government to the potential military applications of nuclear physics, and no atomic bomb project is underway when the *New York Times* publishes a threshold story in early May 1940 on nuclear research toward a bomb in Germany and the United States.
- The *New York Times* article reaches the Soviet Union, and stimulates continued research.
- Two major Soviet contributions, the discovery of spontaneous fusion and the theory of chain reactions, occur—although by this date, Western scientists are focused on a race with their fears of work in Nazi Germany, and largely ignore scientific achievements in the Soviet Union.
- With the Soviet entry into World War II in June 1941, the country's scientists turn to immediate war work, and only a lone scientist—Georgii Flerov at the Leningrad Air Force Academy—realizes that the West is seriously engaged in an atomic bomb effort. In the Russian colloquial, *the dogs that did not bark* had alerted him, with all articles on nuclear fission missing from international journals and their authors gone silent as well.
- As of late 1942, literally during the battle of Stalingrad, the Soviet government formally decides to embark on an atomic bomb project, resuming efforts on "the uranium problem" that had been suspended when the country entered the war the year before.
- The Soviet bomb project under Stalin is small, initiated in early 1943 after the war between Germany and the Soviet Union has turned in favor of the Soviets. The combined Soviet victory at Stalingrad and the bomb project are perhaps the first two Soviet events of the Cold War to come. The Soviet campaign at Stalingrad is code-named Uran—translated as uranium. Stalingrad marks the Soviet Union's emergence as a post-war world power, while successful fabrication of increasingly powerful nuclear weapons will become central to sustaining that power.
- Espionage of 1943-1945 delivers important details of the American bomb project to the Soviet Union.

- The Soviet Union also captures a cadre of German scientists, their laboratory equipment, and some uranium during the occupation of Germany the first half of 1945, with these men later employed to work on the continuing bomb project.
- After the Trinity test in July 1945, President Truman informs Stalin of "a new weapon of unusual destructive force" during the Potsdam Conference (on 24 July).
- In all likelihood, Stalin understands the reference to a successful atomic bomb, and is recorded as requiring Soviet work toward a bomb to accelerate.
- The dropping of atomic bombs on Hiroshima and Nagasaki on 6 and 9 August 1945 dramatically crystallizes the Soviet Union's recognition of the importance of the weapon, and its undeniable future effect on the balancing of world power.

The Cold War Unfolds

A number of histories have catalogued the milestones and events of the Cold War period, with most beginning in 1945. The formal end date of the war is variously interpreted as 1989 (with the fall of the Berlin Wall) or 1991 (the signing of the Strategic Arms Reduction Treaty, the formal end of Strategic Air Command alert by Presidential order, the cancellation of the Peacekeeper Rail Garrison program, and the dissolution of the Soviet Union into the Commonwealth of Independent States). For this study, the end date is proposed as the whole of the several-year denouement, 1989-1991, counterbalancing what is a more accurate start date of 1944-1945. From an Air Force perspective, too, the realignment of its major commands in mid-1992 speaks strongly for continuing the discussion of the war through 1991. The emergence of Air Force Materiel Command from the former AFSC and AFLC marks the end of an era where R&D in particular had been in a spotlight. In a parallel reorganization, Air Combat Command absorbed Strategic Air Command (SAC) and the heritage of Curtis LeMay—both major symbols of the American Cold War. The shift in symbolism that occurred within the Air Force during 1991-1992, bookended the profound interpretation of the Berlin Wall in 1989.

Below is a Cold War timeline adapted from one compiled by Dr. Rebecca Cameron in *Coming in from the Cold: Military Heritage in the Cold War*, a project of the United States Air Force History Office in Washington, D.C., of 1993. Other timelines exist pertinent to the evaluation of United States Air Force Cold War potential cultural resources. Another excellent source referenced below is *The Cold War and Beyond: Chronology of the United States Air Force 1947-1997* by Drs. Frederick J. Shaw Jr. and Timothy Warnock of the Air Force Historical Research Agency at Maxwell Air Force Base. Both Headquarters Air Mobility Command (at Scott Air Force Base in Illinois) and Headquarters Air Combat Command (at Langley Air Force Base in Virginia) have completed contextual histories, in 1994-1996 and 1994-1997 respectively. Each of these studies includes Cold War timelines, and each weights the mix of political, economic, and military benchmarks differently—with specific scientific achievements partially referenced for the Air Force. Elements from these timelines are also included below, as are documented milestones from other Air Force projects by the author. Additionally, Headquarters Air Education and Training Command (Randolph Air Force Base in Texas) has supported a contextual history for the Cold War, with publication in July 2002. The timeline herein does not employ that study, although it is recommended reading for the bigger Air Force Cold War picture linking mission history to the physical landscape of military facilities.

Organization of a timeline for the Cold War is often divided into larger periods, with bracketing dates that define a group of years as more similar to each other than to the years that come before or follow. The notion of "periods" within the Cold War varies widely, dependent on the point of view of individual authors and the underlying focus of the study to which the timeline is attached. A political study, for example, might structure different periods than an economic one. A look at the key

scientific and technological achievements would generate yet another conceptual framework. Predictably, an American military history would tend to group years together based on a combination of policy focal points and plateaus weighted toward a particular service arm (here, the United States Air Force), intermixed with political milestones and events widely acknowledged as pivotal for the Cold War. Most military history timelines, unless of specialty type, do not include the major benchmarks of science, although logically this is of undisputed importance for the weapons development central to the sustainment of a cold war. Timelines of this type also rarely include the counterpoint of important milestones and events from the Soviet point of reference. The timeline below offers a broadbrush framework of the Cold War, and includes milestones and events that help to structure the more detailed discussions undertaken in Volume I, Parts II-IV, and in the summaries of achievements at the individual installations of Air Force Materiel Command presented in Volume II, Chapters 1-15. The contextual history written for Headquarters Air Combat Command divided the Cold War into four periods, 1945-1952, 1953-1963, 1964-1980, and 1981-1989. This study adjusts that framework slightly.

Periods presented here are:

- the early Cold War, 1945-1954

  opening with events tied to the threshold achievement of an atomic bomb and concluding with the phasing in of the thermonuclear (hydrogen) bomb,

- the middle buildup years, 1955-1962

  characterized by a building up of many American and Soviet weapons and defense systems, from air defense command posts and radar networks, to improved bombers and fighter aircraft, to increasingly powerful nuclear bombs and long-range missiles, and abruptly terminated with the Cuban missile crisis in late October 1962—a seminal event from both the American and Soviet perspective,

- the plateau of international awareness and counterinsurgency wars on third-party soils, 1963-1975

  including the long Vietnam War and events in the Middle East, and further defined by parallel American and Soviet successive achievements toward an antiballistic missile defense system, as well as international restrictions on nuclear weapons testing and first-strike use of biological and chemical munitions, and

- the joint American-Soviet escalation leading to the war's end, 1976-1991

  a final period of development and deployment for sophisticated weapons systems, raising new concerns in both nations and ultimately exhausting the Soviet economy.

The timeline that follows highlights the countries involved in the American-Soviet struggle to illustrate the international character of the war.

The Early Cold War, 1945-1954

1945

August	The United States announces its intention to occupy **Korea** south of the 38^{th} parallel, coupled with the intention of the Soviet Union to occupy the north. ... The Soviet Union establishes the Special Committee on the Atomic Bomb, with the intention of modeling the Soviet weapon on detailed specifications of the American bomb (then in hand).
September	Ho Chi Minh's troops take power in Hanoi and proclaim an independent **Vietnam**. ... The first group of German scientists arrive in the United States under Project Paperclip.
November	In elections held in **Hungary**, the Communist Party achieves only 17% of the vote, after which Stalin moves to eliminate opposition. Hungary becomes a Communist state under Marshall Tito. ... The American Joint Chiefs of Staff prepare the first list of Soviet targets for atomic attack.

Beginning in 1946, the American Pentagon supported successive war plans using atomic bombs, code-named through 1950 as Pincher, Broiler, Grabber, and Sizzle. During 1945-1946, the United States and Britain withdraw their occupation troops from **Iran**. The Soviet Union does not.

1946

January	**Canada**'s top-secret atomic energy plant at Chalk River becomes operational. ... The United Nations holds its first meeting of the General Assembly in London, with 51 nations attending.
February	American Secretary of State James F. Byrnes announces a "get tough with Russia policy" at the Overseas Press Club in New York.
March	Winston Churchill makes his Iron Curtain speech at Westminster College in Fulton, Missouri. President Truman is in the audience. ... General Carl Spaatz, American War Department Chief of Staff, reorganizes the Army Air Forces into three operational commands: SAC, Tactical Air Command (TAC), and Air Defense Command (ADC). Air Materiel Command continues to sustain the R&D and production-logistics mission for the Army Air Forces. ADC activates the first Aircraft Control & Warning squadron.
April	General Spaatz recommends that the Air National Guard expand to take on the primary air defense fighter-interceptor mission of ADC.
May	**Canada** and the United States establish the Military Co-operation Committee. Each country sends members of its Army and Navy, as well as diplomatic representatives, to discuss initial strategies at a meeting of the Canada – United States Permanent Joint Board on Defense. The Committee designates 1950 as the first critical year for potential Soviet nuclear attack on the North American continent. ... The Army Air Forces give Douglas Aircraft Company an R&D project to study American air defense and its integration with evolving technologies. The RAND (research and development) project becomes a nearly independent arm of Douglas, and is an autonomous nonprofit organization as of 1948. RAND analyzes tactical and strategic missions of the United States Air Force.
June	Bernard Baruch presents President Truman's international atomic energy control plan to the United Nations. The Baruch Plan proposes to place the control of fissionable materials under a United Nations agency with inspection powers. The Plan also would outlaw the manufacture of atomic bombs, would require the dismantling of

	those already existing, and would share atomic energy knowledge between nations. The Soviet Union does not accept inspection within its borders. In counterpoint, the United States is wary of submitting its scientific technology to Soviet review. The Baruch Plan, very important as a proposed check-and-balance for the buildup of nuclear weapons, fails. ... A national referendum in **Poland** approves Communist reforms. ... Communist Chinese leader Mao Tse-tung strongly requests that the United States cease the supply of arms to the Nationalist Chinese and evacuate American forces from **China**.
July	The United States detonates two atomic bombs in the **Bikini Atoll** of the **Marshall Islands** in the Pacific. Massive preparations for the tests, code-named Crossroads, had occupied the first six months of the year. The first test, *Able*, occurs on 30 June and uses a mixed fleet of Japanese, German, and American ships—92 target ships for an airborne detonation over the array. The second test, *Detector*, takes place on 25 July as an underwater burst. ... The United States possesses a stockpile of nine atomic bombs at mid-year.
August	The Atomic Energy Act (McMahon Act) establishes the Atomic Energy Commission (AEC), a five-person civilian board authorized to develop and control all military and civilian facets of atomic energy.
December	The United States and **Britain** agree to merge the economies of their occupied sectors in **Germany**. ... Viet Minh and French forces clash in **Vietnam**, marking the start of an eight-year French Indochina War. ... American Secretary of War Robert Patterson and Secretary of the Navy James V. Forrestal establish the Armed Forces Special Weapons Project (AFSWP). The AFSWP becomes responsible for the armed forces' development of nuclear weapons. The AFSWP works with the Sandia Laboratories (Sandia Base) on Kirtland Air Force Base in Albuquerque, New Mexico, and helps to expand the labs for nuclear weapons production, testing, and the engineering of storage facilities.

Also during the year, the first all-electronic digital calculator, known as the electronic numerical integrator and calculator (ENIAC), is in test by the United States Army at the Aberdeen Proving Ground in Maryland. ENIAC can not store information, but the machine significantly enhances the speed and accuracy of computations (first used for ordnance tables). Scientists and mathematicians immediately understand that computers will make the necessary high-speed calculations required to develop advanced nuclear weapons. ... By the end of 1946, Soviet scientist Andrei Dmitrievich Sakharov proposes a layered fission-fusion-fission bomb, called First Idea (alternately, Layer Cake). This design for a thermonuclear bomb parallels the independent work of American scientist Edward Teller at this same time for Alarm Clock.

<u>1947</u>

March-April	Representatives of the United States, **Britain**, and the Soviet Union meet in Moscow to decide on a form of government for post-war Germany. Meetings end without an agreement between the three countries. ... In March, President Truman announces the Truman Doctrine, a policy for containment of Soviet aggression. Immediate concerns are in **Greece** and **Turkey** where Communist guerrillas are in place. In counterpoint, the Soviet Union attacks the United States as "warmongers" in a meeting of the General Assembly of the United Nations.
May	A Communist government takes over **Hungary**.
June	American Secretary of State George C. Marshall calls for European economic recovery assisted by the United States. Representatives of Soviet **Eastern Europe** walk out of the Paris meeting.

July	American diplomat and Soviet expert George F. Kennan publishes a key article in *Foreign Affairs* (as Mr. X). The article, "Sources of Soviet Conflict," outlines a possible policy of "a long-term, patient but firm and vigilant containment of Russian expansive tendencies...designed to confront the Russians with unalterable counter-force at every point where they show signs of encroaching upon the interests of a peaceful and stable world." Kennan discusses the Soviet character, the country's deep-seated need for territorial defense, and the likelihood that a sustained situation would play out on the world stage. Kennan envisions a "duel of infinite duration," requiring "the adroit and vigilant application of counter-force at a series of constantly shifting geographical and political points, corresponding to the shifts and maneuvres of Soviet policy." In short, Kennan defines *a cold war*, a conflict which he interprets could last for 10 to 15 years. ... Prominent American journalist Walter Lippmann reacts immediately to Kennan's article (aware of the identity of Mr. X) and writes *The Cold War: A Study in U.S. Foreign Policy*. Published before the close of 1947, *The Cold War* formally names the conflict at hand. The war's duration would be 45 years, not 15. ... President Truman signs the National Security Act that unifies American armed services as the National Military Establishment under a Secretary of Defense. The Act establishes the National Security Council, a body that will issue important American Cold War policy statements. The National Security Act also creates the United States Air Force, a direct follow-on to the nearly independent Army Air Forces of World War II. Truman appoints Philadelphia attorney Thomas K. Finletter to direct the Air Policy Commission (the Finletter Commission). This body, like RAND, will contribute key published air policy analyses.
October	The United Nations authorizes the creation of **Israel.** ... Captain Charles (Chuck) E. Yeager makes the first faster-than-the-speed-of-sound test flight in Southern California (at today's Edwards Air Force Base).
November	The United States initiates testing of the upper atmosphere with the first Aerobee launch (to 190,000 feet). The launch occurs at the White Sands Proving Ground in New Mexico.
December	A Communist regime replaces the monarchy in **Rumania.** ... The American stockpile of atomic bombs reaches 32.

The United States Air Force develops its first formal post-World War II air defense plan, Project Supremacy, between late summer and the end of the year (subsequently approved as the Radar Fence Plan). **Canada** also begins work on an early warning system. The AEC takes steps toward large-scale nuclear testing, and establishes the Pacific Atomic Proving Ground on the **Kwajalein Atoll** in the **Marshall Islands**. In the Soviet Union, scientists initiate efforts toward the computer systems needed for nuclear weapons calculations.

<u>1948</u>

January	The Finletter Report advances the critical year for potential Soviet attack on the United States from 1950 (as projected by the Military Co-operation Committee in 1946) to 1953.
February	The American Joint Chiefs of Staff (also created by the National Security Act) estimates that the Soviet Union possesses 200 Tu-4s. The Tu-4 is a long-range bomber based on the B-29. The Joint Chiefs state that the Soviets could increase this number to 1,000 bombers by 1949. ... A Communist coup occurs in **Czechoslovakia.**
March	**Eastern Europe** becomes increasingly unstable. The American Military Governor of **Germany**, Lucius D. Clay, estimates that war with the Soviet Union is eminent. **Belgium, England, France, Holland**, and **Luxembourg** sign the Brussels Treaty to

	create an Atlantic regional mutual-defense pact. President Truman announces to Congress that the Soviet Union is the enemy of the United States. The National Security Council issues a document taking a hard Communist stance (NSC-7). The United States Air Force puts the First Air Force on alert in the Northwest and Alaska in anticipation of Soviet attack.
April	The Soviet Union blockades all entrances from into **West Berlin** in an attempt to force the West to leave the city. ... ADC sets up radar squadrons in the Northwest, the Northeast, and the Los Alamos-Albuquerque area, formalized as the Lashup Radar Network.
April-May	Operation Sandstone occurs at **Kwajalein** (alternately named Milestone or Switchman). The United States sponsors three nuclear tests, *X-Ray*, *Yoke*, and *Zebra*. Sandstone tests use a fission igniter, and prove that a thermonuclear device is possible.
May	The United States formally recognizes **Israel**. The surrounding Arab countries do not. Five Arab countries invade Israel, an event that marks the start of the first Arab-Israeli War. ... The American Joint Chiefs of Staff approve Halfmoon, an emergency war plan that includes a massive atomic air offensive against the Soviet Union. President Truman rejects Halfmoon. The American stockpile of atomic bombs climbs to 56 by about mid-year (110 by year's end).
June	The West begins airlifting supplies to **West Berlin** and counter-blockades **East Germany**.
August	Whitaker Chambers accuses Alger Hiss of being a member of the Communist underground in Washington, D.C. ... The Republic of **Korea** is formed at Seoul, South Korea, after the North boycotted elections (of May).
September	The American Joint Strategic Plans Committee reports to Congress that the Soviet Union will have 20 to 50 atomic bombs by 1952, with delivery capabilities to the United States.

During 1948, SAC increases the number of B-29s modified to carry atomic bombs from 30 to 60, while simultaneously receiving the first B-36s into its inventory.

<u>1949</u>

April	Western nations form the North Atlantic Treaty Organization (NATO) in reaction to the growing Soviet threat. NATO includes **Belgium, Canada, Denmark, France, Great Britain, Iceland, Italy, Luxembourg, the Netherlands, Norway, Portugal**, and the United States. **Greece, Spain, Italy**, and **West Germany** later join the organization.
May	The Soviet blockade of Berlin ends.
June	The American Secretary of Defense establishes the Hull Committee to study mating atomic warheads to missiles. The Hull Committee Report notes that four missiles in development might be operational by 1954, when the committee anticipates that a sufficiently large stockpile of fissionable materials will make such weapons feasible. ... The United States withdraws its troops from **Korea** and leaves only military advisors. Korea is close to civil war.
August	The Soviet Union detonates its first atomic bomb, named Joe-1 by the Americans. ... President Truman signs amendments to the National Security Act of 1947. The amendments convert the National Military Establishment into the Department of Defense.

September	The Allied High Commission relinquishes administration of the American, British, and French occupation zones in Germany. The German Federal Republic (**West Germany**) is established.
October	**East Germany** becomes the German Democratic Republic. ... Mao Tse-tung establishes the **People's Republic of China** as a Communist state. Nationalist Chinese leader Chiang Kai-shek withdraws from mainland China to the island of Formosa (**Taiwan**).

By the close of the year, the AFSWP completes construction of four American National Storage Sites for nuclear bombs: Sites A, B, and C are built into hard-rock locations in New Mexico, Texas, and Tennessee (with Site C including substantial surface construction). Site D is fully aboveground in Louisiana. The American stockpile of bombs reaches 235. The Soviet stockpile at this date is one atomic bomb.

<u>1950</u>

January	In response to the successful Soviet detonation of an atomic bomb, President Truman orders accelerated development of a thermonuclear weapon—the hydrogen bomb. ... The American judicial system convicts Alger Hiss of perjury (after denying his engagement in espionage for the Soviet Union).
February	American Senator Joseph P. McCarthy publicly claims that known Communists are making policy in the Department of State, thus beginning the era of Communist witch hunts under McCarthyism. ... The Soviet Union and the **People's Republic of China** sign the Sino-Soviet Pact as a bilateral defense commitment.
April	The American National Security Council publishes another point paper (NSC-68) calling for a buildup of nuclear weapons and for an increased capacity to fight conventional wars against piecemeal Soviet aggression (such as had been postulated by Kennan in 1947). NSC-68 projects the critical year of Soviet advantage to be 1954 (again shifted forward, from a date of 1953 given in the Finletter Report of 1948). NSC-68 comments that the arsenals of the two growing superpowers alone could provoke war, and that a surprise attack by the country with the advantage is likely.
June	**North Korea**n troops invade **South Korea**, an act that initiates the Korean War. ... By mid-year, SAC increases its nuclear-capable bomber force to 250 planes. The American atomic stockpile includes 298 bombs. Year's end American total is 369; Soviet total, five.
July	A Gallup poll in the United States records that 77% of surveyed Americans approve the use of atomic bombs in any future war.
September	Congress passes the McCarran Internal Security Act to monitor domestic Communist activities in the United States (over the veto of President Truman).
October	Chinese troops support **North Korea**.
December	The United States enters a Mutual Defense Assistance Agreement with **Vietnam**. ... The United States Air Force establishes its northernmost air base at Thule, **Greenland**, nearly 700 miles north of the Arctic Circle.

During 1950, two major espionage incidents illustrate the sensitive nature of the atomic weapons buildup. In February, Klaus Fuchs, a German scientist of Communist ideology who had worked on the British atomic bomb project in the early 1940s and on the Manhattan Project after 1943, is arrested as a Soviet spy in England. Fuchs had decided to inform the Soviets about atomic research after the German invasion of the Soviet Union during World War II. He passed a detailed description of the plutonium bomb to Soviet physicists. Fuchs' information is estimated to have saved the Soviet

Union between one and two years toward the development of a successful atomic bomb. In October, Bruno Pontecorvo, an atomic scientist who had worked at the Canadian Chalk River plant in Montreal into 1949 before joining the British atomic energy project, defected to the Soviet Union. Dr. Pontecorvo had aided the Soviets from the earliest years. He had toured the first American heavy-water plant in Chicago with Dr. Alan Nunn May, another Soviet spy at Chalk River. May had been arrested in 1946, sentenced in British court for espionage in May 1948.

<u>1951</u>

January	Convair undertakes development of a long-range nuclear missile, Project Atlas. Engineers first design the missile to carry a 7,000-to-8,000-pound atomic bomb, travel 5,500 nautical miles, and be accurate to within one mile of its target.
April	The American judiciary system sentences Ethel and Julius Rosenberg to death for atomic espionage.
August	The American and **Canadian governments** formally plan the Pinetree Line, a line of radars with installations straddling the two countries' common border. (The Pinetree Line would include 30 radars, operational in 1954.)
September	The United States signs a peace treaty with **Japan** and negotiates a mutual security agreement with **Australia** and **New Zealand**. Forty-eight nations sign the treaty restoring Japanese sovereignty and independence. The Soviet Union does not sign. A separate United States – Japan treaty allows continued American military bases in Japan.
October	President Truman announces that the state of war with **Germany** is officially ended.
November	In the event of war, the United States and **Canada** agree to disperse fighter-interceptor aircraft to bases in each other's jurisdictions.

In this year, the American nuclear stockpile increases to 640 bombs; Soviet stockpile, 25. American atomic tests in the Pacific occur as a part of Operation Greenhouse during April and May. Pretrials for Greenhouse had taken place at the new Nevada Test Site during January and February (Ranger). The Korean War had made the atomic proving ground in the Pacific seem unstable, and had stimulated finding a test location in the continental United States. More atomic detonations at the Nevada Test Site are underway in August (Buster-Jangle).

<u>1952</u>

January	The Soviet Union restricts the movement of foreign diplomats in Moscow to a 25-mile radius.
April	American atomic tests Tumbler-Snapper go as planned in Nevada.
June	President Truman inaugurates the first American nuclear submarine, the *U.S.S. Nautilus*. (Formal commissioning of the submarine will occur in 1954.)
July	The Ground Observer Corps initiates a round-the-clock Skywatch in the continental United States.
October	The first full-scale explosion of an American thermonuclear bomb occurs in the **Marshall Islands** as Operation Ivy. The detonation blows away the island of Elugelab in the **Eniwetok Atoll** completely, creating an underwater crater 1,500 yards across. The British also test their first atomic bomb this month. The American breakthrough in thermonuclear research suggests lighter, more powerful weapons. Convair, for example, redesigns the Atlas intercontinental ballistic missile (ICBM) for a 3,000-pound warhead.
November	The American people elect Dwight D. Eisenhower as President, ending the first years of the Cold War under Truman. Before leaving office, Truman had authorized

another increase in the production of atomic bombs. The year's stockpile increases to 832 bombs. Eisenhower had announced his New Look plan for American defense in May, a plan that would focus on maximum military effectiveness at a minimum cost.

In 1952, an unmanned microwave fence across **Canada** is also in progress as the Mid-Canada Line (McGill Fence).

1953

March	Soviet leader Josef Stalin dies.
July	Armistice ends the Korean War.
August	The Soviet Union conducts its first hydrogen bomb test. ... In **Iran**, the Shah flees the country, but is subsequently restored by an American-backed coup.

During the year, the National Security Council approves the Distant Early Warning (DEW) Line, a radar project in northernmost **Canada** and the Alaskan Arctic. The Council also continues to emphasize a need for offensive nuclear capabilities able to inflict massive damage (NSC-162/2). Soviet scientists begin work on design of the R-7, an ICBM. In the autumn, the Soviets conduct an exercise in the Carpathian Military District to simulate combat on a nuclear battlefield. Soviet leaders also recommend initiating R&D for an antiballistic missile defense system, in anticipation of American ICBM deployment. The Central Committee Presidium approves the R-7 to carry a nuclear warhead in November. The American nuclear stockpile increases to 1,436 bombs, with 1,000 SAC aircraft able to deliver the weapons. (The Soviet stockpile rises to 120 bombs.)

1954

January	Secretary of State John Foster Dulles announces a shift of American foreign policy toward the Soviet Union. The Truman Doctrine of 1947 had stipulated "containment." Dulles states that the United States would henceforth move to a plan of massive retaliation.
March	The Surprise Attack Panel, created by President Eisenhower and chaired by James R. Killian, reports to the National Security Council on American ability to deter Soviet aggression. Known as the Killian Report, this document once again outlines a timetable for an arms race between the two countries. The Killian Report is influential and recommends a prioritized development of ICBMs, dispersal of SAC's long-range bombers, and increased gathering of intelligence on Soviet activities. ... The AEC announces a new nuclear weapons test series in the **Marshall Islands**. Scientists who later assess the tests make the first reports about the dangers of radioactive fallout.
May	The Soviet Union upgrades its bombers with the M-4, a jet-engined long range aircraft.
July	Geneva Accords divide **Vietnam** into North and South, with a Communist state north of the 17th parallel.
August	President Eisenhower signs the Communist Control Act, an act that outlaws the Communist Party in the United States. ... Communist leader Chou En-lai announces **China**'s intention of liberating Formosa (**Taiwan**) through invasion. President Eisenhower responds that the United States will repel any such attack.
September	**Australia, England, France, New Zealand, Pakistan, the Philippines, Thailand**, and the United States form the Southeast Asia Treaty Organization as an anti-Communist alliance. ... Forty-four thousand Soviet troops participate in a live

nuclear test exercise near the village of Totskoe, in the South Urals Military District. A Tu-4 bomber drops a medium-yield atomic bomb, with the mock offensive and defensive armies entrenched five to eight kilometers (three to five miles) from ground zero. Troops conduct battle exercises in radiation zones. The exercise becomes the basis for updated Soviet field manuals. Chinese top military leaders observe the test with the Soviets. These tests, although not discussed for decades in the open literature, create broad areas of radioactive fallout, complementary to fallout observed in the **Marshall Islands**.

A number of military defense capabilities improve in 1954 for both the United States and the Soviet Union. The American Joint Chiefs of Staff agree to the deployment of nuclear warheads for air-to-air rockets for fighter aircraft, while the jet interceptor the F-86D is operational at most ADC installations. Interceptors in the United States are on alert, with facility expansions occurring at some bases. The command-and-control network for air defense is also in place, with improvements moving forward. The United States establishes radar listening posts in Turkey to monitor Soviet missile tests. More advanced early warning systems are under construction in Alaska. Simultaneously, the Soviet Union deploys a new air defense network around Moscow. When completed in 1956, this system will include radar and antiaircraft units.

The Middle Buildup Years, 1955-1962

1955

January	The United States Air Force decides to contract for an ICBM parallel to the Atlas, using components already under development. The Titan program results. By the end of the year, the Department of Defense would augment ICBM efforts with contracts for two intermediate range ballistic missiles (IRBMs), the Thor and the Jupiter (as a stopgap measure).
March	The United States Army Ordnance Corps contracts Bell Laboratories to conduct an air defense weapons study focusing on an antiballistic network of radars and missiles (the Nike II Project).
April	An American B-36 bomber launches a missile with a nuclear warhead 42,000 feet above the Nevada Test Site. Denotation of the missile causes a nuclear blast at the highest altitude known to this date.
May	**West Germany** becomes a member of NATO. ... The Soviet Union and aligned countries in **Eastern Europe** form the Warsaw Pact, the counterpoint organization to NATO. Member countries are **Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Rumania**, and the Soviet Union.
June	The United States stages its first nationwide civil defense exercise. ... SAC begins to deploy the B-52, a long-range bomber that replaces the B-36.
November	**Britain, Iran, Iraq**, and **Turkey** sign the Baghdad Pact. The United States pledges its military liaison.

During 1955, President Eisenhower proposes an Open Skies Policy at a summit conference in Geneva. Soviet leader Nikita Khrushchev disagrees with the idea that each country should aerially surveil the other. As of about 1954-1955, Soviets also begin construction of an antiballistic missile proving ground near Sary-Shagan in Kazakhstan. The United States also announces its intentions to launch a space satellite by late in the decade, and continues to improve radar defense lines across Canada. President Eisenhower puts forth his California Policy. This program attempts to formally move defense contracting toward the interior of the country, and includes a repositioning of missile

test sites. SAC commissions an underground command post for its headquarters at Offutt Air Force Base this same year, with completion in 1957.

1956

May	A B-52 drops a hydrogen bomb on the **Bikini Atoll** in the **Marshall Islands** in the first American airborne tests of the fully developed weapon.
September	The United States Air Force activates the first tactical missile wing at Hahn Air Base in **Germany**. The Air Force plans to equip the wing with the Matador missile.
October	**Britain, France**, and **Israel** attack **Egypt** (a nation backed by the Soviet Union). The crisis arises from the Egyptian nationalization of the Suez Canal in late July. British and French stockholders held majority ownership of the canal. The issue is access. Egypt's actions follow the United States' retraction of financial aid toward building the Aswan Dam. President Eisenhower threatens use of American nuclear weapons in the region to resolve the situation. Making the situation even more tense, Egypt and the Soviet Union had agreed to a major arms deal at mid-decade, a watershed event. In general as of about the middle 1950s, selected **Middle Eastern countries** were functioning as proxies for arms testing on behalf of the United States and the Soviet Union. **Israel** had also raided the **Gaza Strip** in 1955 and from this point forward asks the United States to sell it weapons. ... **Hungary** revolts against Communist rule. The United States does not assist the endeavor, and the Soviet Union keeps a Communist government in place.
November	Khrushchev makes his "We will bury you" speech to Western diplomats.

In 1956, SAC begins to test the concept of alert for its dispersed bombers. The same year, construction for the next generation of ADC command and control starts is underway (the Semi-Automatic Ground Environment [SAGE]). SAGE, like the network before it, coordinates the actions of ADC's fighter-interceptor squadrons, on alert as of the start of the decade.

1957

January	The Eisenhower Doctrine allows the President of the United States to commit troops to the **Middle East** to stop Communist aggression in the region. Further disturbances in **Jordan** and **Syria** had stimulated the creation of this policy.
June	The first long-range, high-altitude reconnaissance U-2 arrives in the inventory of the United States Air Force.
July	The United States Air Force runs a live test of the MB-1 Genie air-to-air rocket, with its nuclear warhead, at the Nevada Test Site. An F-89J fires the rocket. This is the only live firing of the MB-1 Genie during the Cold War, although Genie-equipped aircraft will stand on alert at multiple American installations during the late 1950s and early 1960s.
August	The Soviet Union announces its first successful test of an ICBM. ... The United States and **Canada** informally establish the joint North American Air Defense Command (NORAD). The command post will takes years to construct under Cheyenne Mountain in Colorado and will be a fully hardened site.
September	The United States runs its first underground nuclear test at the Nevada Test Site.
October	The Soviet Union launches the first satellite to orbit the Earth.
November	The Soviet Union launches a second satellite into Earth orbit, the first to carry a living creature into space.
December	The United States conducts its first successful test of the Atlas ICBM. ... Another analysis of Cold War escalation, the Gaither Report, announces that a survivable

nuclear force is imperative, with the critical year for Soviet capabilities projected as 1959. The timetable for destructive weapons capabilities has continued to advance throughout the 1950s, and is by this date associated with the first-strike potential of ICBMs.

1958

January	The United States launches its first satellite, Explorer I.
March	Khrushchev becomes Premier of the Soviet Union. The Soviet leader holds this position in tandem with his prior position of Secretary of the Communist Party. ... The United States launches its second satellite, Vanguard I. ... The Soviet Union suspends atmospheric nuclear weapons testing.
July	In response to an appeal from President Camille Chamoun of Lebanon, the United States sends a large contingent of Marines into **Lebanon** after an Arab-nationalist uprising there and the overthrow of the government in **Iraq**. TAC supports the effort with a composite strike force. British troops support **Jordan** nearly simultaneously, following the threat of rebel attack on King Hussein. American and British troops withdraw in October.
August	The United States detonates a missile-borne nuclear weapon at high altitude over **Johnson Island** in the Pacific. The test supports development toward an antiballistic missile defense system.
October	The United States and Britain also suspend atmospheric nuclear weapons testing.
December	The United States launches the first artificial communications satellite. President Eisenhower broadcasts a Christmas message via the device.

Both the United States and the Soviet Union continue to advance their nuclear weapons arsenal. R&D on ICBMs moves toward solid-fueled missiles. Launch sites also change to hardened underground silos, with each nation exploring mobile postures for missile positions. In the United States, SAC assumes training and deployment responsibility for all ballistic missiles. Thor IRBM and Atlas ICBM squadrons activate at Vandenberg Air Force Base in California, with the first Atlas operational the next year. In 1958, a retired Royal Air Force pilot Peter George publishes *Red Alert*, a novel that imagines an American attack on the Soviet Union. Columbia Pictures will subsequently release *Dr. Strangelove* in 1964, adapted into a screenplay in 1961 from *Red Alert* by Stanley Kubrick. In 1958 also, **Egypt** joined with **Syria** to form the **United Arab Republic**, and subsequently began receiving renewed economic and technical aid from the United States. Terrorist raids along **Israel**'s borders with Egypt, **Jordan**, and Syria had been continuous from mid-decade forward. **Yemen** joined the pan-Arabic state until 1961, when both Syria and Yemen withdrew from the United Arab Republic. (Egypt continued to use the name for another decade.) A Communist uprising also occurs in **Laos** this year, adding to the heightened instability in **Southeast Asia**.

1959

January	Fidel Castro's dictatorship comes to power in **Cuba**. The next year the Soviet Union will supply arms to Castro, with Cuba aligned with Communism.
February	The United States Air Force launches the first successful Titan ICBM.
April	The United States Air Force tests the Hound Dog supersonic missile over the Gulf Test Range at Eglin Air Force Base. The Hound Dog will carry a nuclear warhead and will augment 20 SAC alert installations. ... The United States Naval Research Laboratory announces that Soviet nuclear tests conducted during the previous autumn have increased atmospheric radioactivity in the eastern United States by 300%. ... Fidel Castro visits the United States.

May	The United States signs agreements with **Canada, the Netherlands, Turkey**, and **West Germany** to provide information and equipment toward training these nations in the use of nuclear weapons.
July-August	Senator Richard Nixon and Premier Khrushchev debate Capitalism and Communism during an American visit to the Soviet Union.
September	A Soviet spacecraft reaches the moon, but crashes on landing. ... Premier Khrushchev visits the United States, meeting with President Eisenhower at Camp David.
October	The first Atlas ICBM goes on alert at Vandenberg Air Force Base in California. This is the first American ICBM with a nuclear warhead placed on alert. Premier Khrushchev visits Vandenberg during his trip to the United States, passing through the installation by rail.

1960

February	**France** detonates its first atomic bomb.
May	The Soviet Union shoots down an American U-2 spy plane, holding the pilot Francis Gary Powers captive. An East-West summit conference in Paris, attended by both President Eisenhower and Premier Khrushchev, collapses as a result of the U-2 incident. Khrushchev withdraws an invitation to Eisenhower to visit the Soviet Union. The Soviet Union sentences Powers to prison for espionage. The two countries exchange spies the next year, with Powers traded for Rudolf Abel. The Soviet Union shoots down a second U-2 over its territory in July, with two American survivors imprisoned into 1961. ... SAC places one-third of its bombers and tankers on 15-minute alert.
June	American Thor IRBMs begin an alert posture at selected British air bases.
July	The United States fires its first ICBM (a Polaris missile) from a submerged submarine off Cape Canaveral, Florida.
August	The first full Atlas ICBM squadron, with six missiles, is operational at F.E. Warren Air Force Base in Wyoming. ... The American Corona spy satellite system completes its first successful mission.
December	Boeing carries the design of a rail-mobile ICBM to full-scale mockup for SAC (Project Big Star). The United States Air Force subsequently cancels the program, but the idea returns as Rail Garrison at the end of the Cold War. ... Ho Chi Minh, Communist leader of **North Vietnam**, announces his intentions to reunite Vietnam under his rule and to remove all American forces from the country. The United States Army had sent small teams of Special Forces to South Vietnam as of the preceding February. The United States had agreed to train South Vietnamese military forces when the French withdrew from the country in early 1955, but had only haphazardly carried out it commitments under the Eisenhower administration.

More Atlas squadrons become operational, augmented by three Titan squadrons, before the close of the year. SAC begins testing its airborne command post, Looking Glass, at its headquarters installation, Offutt Air Force Base. Premier Khrushchev announces a "wage and win" policy of nuclear war. The United States begins testing of an antiballistic missile defense system through an Army program set up in the **Marshall Islands**.

1961

January	President Eisenhower breaks diplomatic relations with **Cuba** in one of the final acts of his administration.

February	A network of three large radar installations becomes operational for early warning of Soviet ICBMs. During the late 1950s, American intelligence had discovered a system of very large radars under construction in the Soviet Union, which had stimulated the Ballistic Missile Early Warning System (BMEWS) project. The United States Air Force locates BMEWS at sites in Alaska, England, and Greenland. NORAD operates the network to provide SAC with early warning of a possible Soviet missile attack, thus allowing SAC to get its alert bomber force airborne. BMEWS is the first early warning network to incorporate the scientific mainframe computer (with duplexed IBM 7090s at each site). The counterpoint Soviet system, named Hen House by American analysts, went in place between 1955 and the early 1970s, and included 11 radars at six locations (interpreted as comparable to BMEWS). ... SAC's airborne command post Looking Glass is operational. Looking Glass uses converted KC-135s to maintain an uninterrupted 24-hour-a-day post, with aircraft airborne in shifts.
April	Soviet astronaut Yuri Gagarin is the first human to orbit the Earth. ... One thousand American-trained Cuban refugees fail in an attempt to recapture **Cuba** from the Castro government (Bay of Pigs).
May	Astronaut Alan Shepard makes a suborbital flight as the first American in space. ... President John F. Kennedy increases American involvement in **Vietnam**.
June	President Kennedy meets with Premier Khrushchev in Vienna on **Berlin**, **Laos** (toward a sustained neutrality in the growing Southeast Asian conflict unfolding in **Vietnam**), and issues of disarmament. The discussions end without agreements.
July	SAC places 50% of its bombers and tankers on 15-minute alert.
August	**East Germany** closes the Brandenburg Gate to construct the Berlin Wall between the east and west parts of the city. President Kennedy indicates that the United States might go to war over the situation in Berlin. The wall is complete by 18 August, with six heavily guarded crossing points.
September	The Soviet Union and United States both resume nuclear weapons testing, with first Soviet tests aboveground and American tests underground.
December	American Corona spy satellites detect construction of a Communist Chinese nuclear test site. ... SAGE becomes fully operational at 23 sites throughout the continental United States.

During 1961, the Cold War continues to escalate. While estimates of operational Soviet ICBMs drop from 200 to between 10 and 25, the United States activates six more Atlas ICBM squadrons: the American Atlas program totals 133 missiles. The United States also deploys the final three Titan I squadrons this year, and tests the first Minuteman (a solid-fueled ICBM). Before the close of the year, the United States Air Force formally begins considering locations for the first large phased-array radar, a radar that will function for space tracking and early warning of ICBM flight paths. The world's first large phased-array radar will begin construction at Eglin Air Force Base in Florida during late 1962 (operational in autumn 1968). The United States Army simultaneously initiates testing on the **Kwajalein Atoll** in the Pacific for a similar radar to meet the needs of the American antiballistic missile defense program.

<u>1962</u>

January	The East-West Conference Banning Nuclear Weapons Tests, ongoing in Geneva since 1958, deadlocks. ... Both the United States and the Soviet Union remove their tanks from patrol along the **Berlin** Wall in order to lessen tensions.
February	John Glenn is the first American to orbit Earth.

April — The first Titan I ICBM squadron is operational at Lowry Air Force Base in Colorado. ... The United States resumes atmospheric tests of nuclear weapons.

July — A Thor IRBM carries a thermonuclear device to an altitude above 200 miles during Operation Dominic at **Johnson Island** in the Pacific. Detonation marks the highest American thermonuclear blast during the Cold War. The series of American high-altitude nuclear detonations near Johnson Island includes one test, Starfish Prime, that is the first to reveal the magnitude of electromagnetic pulse disturbance possible during nuclear combat. Starfish Prime fouls electrical equipment in large numbers as far away as Hawaii—800 miles from the blast. ... A Nike-Zeus missile fired from the **Kwajalein Atoll** intercepts an Atlas ICBM fired from Vandenberg Air Force Base. The test is the first known successful trial for an antiballistic missile defense system.

October — The Minuteman I ICBM becomes operational. ... An American reconnaissance overflight of **Cuba** documents missile sites and bomber bases under construction. Soviet IRBM and medium-range ballistic missile components, as well as other weapons systems, had arrived in Cuba steadily as of summer. President Kennedy declares a quarantine on Cuba, blockading the arrival of additional munitions. All American military bases go to a state of high alert. The six-day period of heightened tension, known as the Cuban Missile Crisis, marks a major event in the Cold War for Americans and Soviets alike. Concessions from both sides resolve the situation: Premier Khrushchev agrees to remove Soviet missiles and nuclear-weapons-capable bombers from Cuba and dismantle their installations, while in counterpoint President Kennedy agrees to remove American IRBMs (Jupiters) from Turkey and stop attempts at an American-backed invasion of Cuba. Stand-down actions continue during the remainder of the year.

In 1962, President Kennedy establishes the Post-Attack Command and Control System, airborne command posts that absorb Looking Glass at Offutt Air Force Base in Nebraska (Headquarters SAC) and the National Emergency Airborne Command Post at Andrews Air Force Base in Maryland. The command and control system includes auxiliary posts for the two aircraft at three additional American Air Force installations, with support squadrons at four other bases.

International Awareness and Counterinsurgency, 1963-1975

<u>1963</u>

April — After a six-hour delay in reliable communications between the United States and the Soviet Union, the two countries agree to set up a hot-line directly linking the nations to avoid misunderstandings and the start of an accidental nuclear war. A cable teletype link between the White House and the Kremlin is going in place by June, operational in August.

June — As of this month, 5,000 United States Air Force personnel were in **Vietnam**, involved in an advisory buildup there. ... The first Titan II ICBM squadron activates, at Davis-Monthan Air Force Base, Arizona.

August — The United States, Britain, and the Soviet Union sign the Limited Test Ban Treaty, agreeing to cease testing nuclear weapons in the world's oceans, atmosphere, and space. One hundred thirteen nations also sign the treaty by the year's close. **France** and **Communist China** do not sign.

October — The United States Air Force launches two satellites from Cape Canaveral as a part of a space-based nuclear detection system. The two satellites, Project Vela Hotel and Project 823, orbit at an altitude of 7,000 miles to detect nuclear detonations worldwide.

November	**Cambodia** accuses the United States of subversive activities from military bases in neighboring **South Vietnam** and subsequently severs relations. ... President Ngo Dinh Diem is assassinated in **South Vietnam**. ... President Kennedy is assassinated in Dallas, Texas. Vice President Lyndon B. Johnson assumes the American Presidency.

<u>1964</u>

April	The number of SAC ICBMs on alert matches the number of the command's bombers on alert for the first time. Hereafter, ICBMs will begin to dominate SAC's alert posture. ... The National Aeronautics and Space Administration (NASA) inaugurates the *Gemini* series that will feature the first American manned orbital spacecraft.
May	The Soviet Union formally displays antiballistic missiles in Moscow's Red Square. ... The United States sends light military aircraft to **Laos** for use by anti-Communist forces.
July	An American spacecraft, *Ranger 7*, impacts the moon after completing its mission of sending more than 4,300 close-up photographs of the lunar surface back to Earth. *Rangers 1-6* failed their missions in some capacity, although both *Rangers 4* and *6* also impacted the moon without transmitting images (in April 1962 and February 1964, respectively).
August	Following the attack of two American destroyers in the **Gulf of Tonkin**, Congress approves the Gulf of Tonkin Resolution giving President Kennedy the power to take necessary measures to prevent further aggression in the region and to stop attacks on the United States there. The first American troops begin to deploy to **Vietnam** in larger numbers, changing the nature of the United States involvement in the Southeast Asian conflict.
September	President Johnson announces American development of the over-the-horizon backscatter radar, a radar that possesses the capability of seeing around the Earth's curvature to detect Soviet ICBM launches immediately post-firing.
October	Political forces in the Soviet Union oust Khrushchev as Premier and Secretary of the Communist Party (Soviet Party Chairman). Leonid Brezhnev replaces Khrushchev in the latter position; Alexei Kosygin in the former. ... **Communist China** conducts its first successful test of an atomic bomb.
December	The SR-71, a sophisticated American spy plan able to fly at above 45,000 feet at 1,000 miles per hour, takes its maiden test flight at Air Force Plant 42 in Palmdale, California, near Edwards Air Force Base. The first SR-71 strategic reconnaissance wing will activate at Beale Air Force Base in northern California in early 1965.

<u>1965</u>

January	President Johnson announces the short-range attack missile (SRAM), a nuclear-tipped cruise missile fired from a B-52 or F-111 able to hit targets up to 50 nautical miles distant from the point of firing. SAC will upgrade and expand a number of its alert bomber facilities for the SRAM during the early and middle 1970s.
March	The first United States Marines deploy to **Vietnam**. ... SAC launches the first American ICBM from an operational base in the United States (at Ellsworth Air Force Base in South Dakota). To conduct the test, SAC uses a tethered, unarmed Minuteman I. Previously, tests using tethered Minuteman I ICBMs had occurred at Edwards Air Force Base in California.

May — President Johnson sends American troops to the **Dominican Republic** to prevent the rise of another Communist state.

June — The final Minuteman I ICBM is operational (at F.E. Warren Air Force Base in Wyoming). The total Minuteman I force deployed is 800 missiles in the continental United States. SAC had deactivated all first-generation Atlas ICBMs as of the previous April.

August — SAC emplaces its first Minuteman II ICBM at Grand Forks Air Force Base in North Dakota, continuing the nuclear arms escalation. ... *Gemini 5*, carrying two American astronauts, establishes five world records in space. The spaceflight superceded four records held by the Soviet Union up to this date.

December — *Gemini 7* establishes 11 world records for manned spaceflight. ... American military forces in **Vietnam** climb to over 184,000 by the end of the year.

1966

January — A B-52 crashes over the coast of **Spain**, dropping four unarmed hydrogen bombs. Two of the bombs rupture and scatter radioactive debris requiring massive American cleanup efforts. One lands in the ocean and results in months of search for its successful retrieval.

May — American forces fire on targets in **Cambodia** for the first time.

June — *Surveyor I* lands on the moon.

October — **France** continues to detonate nuclear devices in the atmosphere. **Communist China** tests a missile with nuclear warhead, also in an atmospheric test.

December — American involvement in the **Vietnam** War climbs to 362,000 troops.

During 1966, the Soviet Union deploys the world's first antiballistic missile network of radars and missile emplacements around Moscow. The United States continues work toward its antiballistic missile defense, planned for emplacement near the fields of Minuteman silos at Grand Forks Air Force Base in North Dakota. The American program initially has the name Sentinel (as of 1967), evolving into the Safeguard program by the early 1970s. The Soviet network is known as Galosh. Soviet and American antiballistic missile defense networks are a high priority as of this date, thought to cripple the effectiveness of a retaliatory nuclear attack. To make nuclear first-strike or retaliatory attack more successful, both countries move toward multiple independently-targetable reentry vehicles (MIRVs) for single ICBMs. The technology of programming multiple nuclear warheads to several targets independent of one another would be important in the continuing arms race. American deployment of MIRVs would start with the Minuteman III in 1970s, with three warheads per ICBM.

1967

January — The United States, Soviet Union, and 60 other nations sign the Outer Space Treaty to limit the military use of space. ... NASA's *Apollo* program, with goals of landing a man on the moon, suffers a major setback during a preflight rehearsal at Cape Kennedy (formerly, Cape Canaveral). Three American astronauts die in a catastrophic fire.

February — All countries in **Latin America**, except **Cuba**, sign the Treaty of Tlatelolco, to prohibit the manufacture of nuclear weapons. ... NORAD becomes fully operational in its hardened command post under Cheyenne Mountain, Colorado.

April — A Soviet astronaut dies on reentry to the Earth's atmosphere after 18 orbits. The Soviet test is the only manned spaceflight of the year by any nation. American manned flights remain suspended after the *Apollo* accident.

June	The Six-Day Arab-Israeli War indicates heightening tensions in the **Middle East**. Both the Soviet Union and the United States have permanent naval presences in the region. By this date, the Middle East is the most heavily armed region in the nonindustrial world. The Soviet Union was providing military equipment to 10 Middle Eastern countries; the United States to nine; Britain to 12; France to six; and, Communist China to one. Foreign arms suppliers had shipped 2,700 combat jet aircraft to the region, along with over 4,000 tanks and large quantities of munitions. ... **Communist China** detonates its first hydrogen bomb.
July	President Johnson and Premier Kosygin hold talks in the United States.
October	A Soviet space probe lands on Venus.
December	American troops in **Vietnam** approach a half million.

In 1967, the Pentagon began its Strategic Missile (Strat-X) Study, an effort continuing into 1969. The Pentagon invited a competitive response from American military service arms for basing modes for what would become the MX ICBM. The MX Peacekeeper would feature 10 MIRVs, and would be an advancement over the Minuteman III.

<u>1968</u>

January	Noteworthy Socialist reforms occur in **Czechoslovakia**. ... North Vietnamese forces conduct the Tet Offensive against South **Vietnam**. ... A **North Korea**n patrol seizes an American intelligence ship, the *U.S.S. Pueblo*, off the Korean coast. North Korea releases the American crew in December. ... A second B-52 carrying four unarmed hydrogen bombs crashes. The incident occurs near Thule Air Base in **Greenland**. Radioactive debris is spread across the ice.
March	The My Lai Massacre occurs and the war in **Vietnam** continues to escalate. President Johnson halts American bombing in North Vietnam north of the 20th parallel. The number of American causalities in the Vietnam War now surpasses the total during the Korean War.
April	The AEC detonates the largest American hydrogen bomb to date, 3,800 feet underground at the Nevada Test Site. The explosion causes an artificial tremor felt in California coastal cities.
April-May	The United States and **North Vietnam** move toward peace talks to end the war. The two countries agree on Paris as the site for the talks, with formal initiation in May. Little progress occurs and hostilities continue unabated in Southeast Asia.
July	The United States, Soviet Union, and 60 other nations sign the Nuclear Arms Nonproliferation Treaty. The treaty states that the United States, **Britain**, and the Soviet Union would be the only countries allowed to maintain a nuclear military force and that they would continue to work toward disarmament. Treaty opening and signing occurs simultaneously in Washington, D.C., London, and Moscow. **France**, **China**, and **India**, who also have made nuclear weapons advancements by this date, do not sign the treaty. ... Direct airline service is inaugurated between the United States and the Soviet Union by Pan American World Airways and Aeroflot.
August	Armed forces of the Soviet Union, **Poland, East Germany, Hungary**, and **Bulgaria** invade **Czechoslovakia**, ending Socialist reform experiments of earlier in the year. ... The United States Air Force launches the first Minuteman III in tests at Cape Canaveral. The Minuteman III is capable of attacking three targets simultaneously.
October	Three American astronauts complete an 11-day orbit of the Earth in the *Apollo 7* mission. ... At the end of the month, President Johnson halts American bombing over **North Vietnam**. The United States widens the forum underway at the Paris Peace Talks through an invitation to South Vietnam at the beginning of November.

December	*Apollo 8* achieves man's first orbit of the moon. ... American troops in **Vietnam** number 535,000.

In 1968, the United States and the Soviet Union participate in sessions toward the Strategic Arms Limitations Talks (SALT) to discuss limits on ICBM and antiballistic missile systems and to ban further advancements in nuclear weapons. Negotiations halt with the Soviet invasion of Czechoslovakia in August. President Nixon changes the American antiballistic missile defense program name from Sentinel to Safeguard during the year.

1969

February	NASA launches *Mariner 6*, an unmanned probe, toward Mars.
March	The United States begins bombing **Cambodia**.
April	**North Korea** shoots down a United States Navy intelligence plane over the Sea of Japan. All crew members perish.
July	*Apollo 11* marks the first lunar landing mission. American astronauts walk on the moon with photographic and voice transmission sent back to Earth. ... Under the Nixon Doctrine advocating the "Vietnamization" of the war, President Nixon orders the first of 25,000 American troops out of **Vietnam**. Nixon announces subsequent withdrawals in September (35,000 troops) and December (50,000 troops).
September	Communist leader of **North Vietnam**, Ho Chi Minh, dies. ... The AEC declares the **Bikini Atoll** to be unsafe for human habitation. Bikini was the site of 23 nuclear detonations during 1946 to 1958.
November	Formal discussions for SALT begin between the United States and the Soviet Union in Helsinki, **Finland** ... President Nixon renounces the use of biological warfare agents, also formally opposing a first-strike use of selected chemical munitions. Nixon orders the destruction of American stocks of biological agents.

By the end of 1969, the United States and the Soviet Union reach strategic parity in their stockpiles of equivalent offensive and defensive weapons systems.

1970

February	American Secretary of State Henry Kissinger begins negotiations with Le Duc Tho, the principal spokesman for the North Vietnamese delegation, at the Paris Peace Talks.
March	The Nuclear Arms Nonproliferation Treaty goes into effect.
April	United States troops invade **Cambodia**. ... SAC reorganizes its Post-Attack Command and Control System, with a reorientation toward host Air Force bases in the interior of the continental United States. ... *Apollo 13* aborts due to catastrophic mechanical failures. The astronaut crew survives.
July	The first class of **Vietnam**ese complete pilot training at Keesler Air Force Base in Mississippi as a part of President Nixon's Vietnamization of the war in Southeast Asia.
August	The first Minuteman IIIs become operational at Minot Air Force Base in North Dakota. ... The United States agrees to modernize Spanish military forces in exchange for continued use of four American air bases in the country.
November	An American attempt to rescue prisoners of war from a camp at Son Tay, near Hanoi, fails.
December	American forces in **Vietnam** decreases to 334,000.

The United States Air Force initiates the Cobra intelligence-gathering program that will include a series of surveillance projects focused on Soviet ICBM launches. The Cobra Dane large phased-array radar in the **Aleutians** was one such project of the early 1970s.

1971

July	*Apollo 15* completes a successful lunar exploration mission.
November	The **People's Republic of China** (Communist China) joins the United Nations.

This year the United States Air Force requests permission to develop and deploy the MX. The Air Force set up an MX Office during 1973, with R&D for the advanced ICBM occurring between 1971 and 1975. Soviet design of a comparable ICBM, the SS-24, will begin in about 1974.

1972

February	President Nixon visits the **People's Republic of China** and pledges to withdraw American military forces from **Taiwan**.
March	SAC receives its first SRAM off the production line.
April	The United States initiates heavy attacks on **North Vietnam** for the first time since cessation of bombing in late 1968. ... The United States and the Soviet Union sign the Biological Weapons Convention, with 80 additional nations following their leads. The convention derives from two years of continued negotiations that had begun with President Nixon's public statement against the use of biochemical warfare agents in late 1969.
May	President Nixon and General Secretary Brezhnev sign SALT I. The agreement limits the number of each country's land- and sea-based ICBMs at their existing levels and restricts development of antiballistic missile defense for five years. ... Nixon and Brezhnev also sign an agreement on the basic principles of détente between the United States and the Soviet Union. The agreement recognizes the Soviet Union's role in **Eastern Europe** and opens economic markets. ... The United States and the Soviet Union additionally sign the Antiballistic Missile Treaty this month, an agreement that bans territorial defense against antiballistic missiles. The treaty makes both countries equally vulnerable to nuclear attack. As initially written, the Antiballistic Missile Treaty allows each nation two site-specific antiballistic missile installations: one to protect the capital city and one to defend a major ICBM installation. The Soviet Union's antiballistic missile system surrounding Moscow had been operational since 1964, while that of the United States was under construction near Grand Forks Air Force Base in North Dakota. Changes to the treaty in 1974 will allow each country only one antiballistic missile site (Moscow and Grand Forks).
September	Loring Air Force Base in Maine becomes the first SAC base to make the SRAM operational in a sustained alert posture.
October	The United States again stops bombing in **North Vietnam** above the 20th parallel. ... President Nixon and General Secretary Brezhnev meet at the Moscow Summit.
December	*Apollo 17* makes the final American manned landing on the moon. ... The Paris Peace Talks break down and President Nixon orders renewed bombing in **North Vietnam**.

1973

January	President Nixon announces the end of the Vietnam War. The Paris Accords set a cease-fire and orchestrate political settlement of the war.
February	The 30-year civil war in **Laos** ends with a cease-fire. The United States ends air strikes in that country.
March	The last American soldiers leave **Vietnam**.
April	The United States Air Forces in Europe (USAFE) agrees to train the **Iran**ian Air Force in F-4 operations. ... The United States resumes bombing North Vietnamese positions in **Laos**.
May	**East and West Germany** establish formal diplomatic relations.
August	The United States ceases bombing in **Cambodia**.
October	Tensions in the Middle East escalate. The Yom Kippur War occurs between **Israel, Egypt**, and **Syria**. The United States airlifts more than 22,000 tons of war materiel to Israel. (As of 1969, the United States had supplied Israel with more than 200 F-4s. Egypt had also encouraged a major buildup of Soviet arms within its borders beginning in 1970.) **Arab** oil-producing **nation**s declare an embargo against the United States. Analysts sometimes characterize the situation in the Middle East of this period as a series of "split-level" arms races, where the arms suppliers of the United States and the Soviet Union are as engaged in the successive conflicts as their clients. NATO tactics and force structure will reflect American military technologies tested in the Yom Kippur War within two years.

1974

March	Indictments occur for the Watergate burglary. President Nixon is named as a co-conspirator. ... The Arab oil embargo ends.
May	Presidential impeachment hearings begin in the United States. ... **India** conducts an underground nuclear test.
August	President Nixon resigns and Gerald Ford takes office.

During 1971-1974, the American people begin to view leadership at the top levels with a new eye due to the publication of the Pentagon Papers by the *New York Times* beginning in February 1971; the Watergate burglary in June 1972; and, President Nixon's resignation in 1974.

1975

April	The Khmer Rouge are victorious in **Cambodia**. The United States ends its official presence in the country and Marines evacuate. ... The United States evacuates Saigon, **South Vietnam**, and that nation falls to **North Vietnam** advances. ... The Vietnam War formally concludes on 30 April.
July	The United States and the Soviet Union sign the Helsinki Accords. The two nations pledge to accept existing European borders, protect human rights, and promote economic and cultural exchange. ... American and Soviet astronauts link up in space.
October	The American antiballistic missile defense site, Safeguard, becomes operational in North Dakota (deployed in April).
December	The United States Congress stipulates the inactivation of Safeguard, and in 1976 the United States Army dismantles the radars and missile emplacements. The large phased-array early warning radar transfers to the United States Air Force and continues as a major detection installation. During 1975-1979, the Air Force also oversees design and construction of the first two large phased-array radars for

monitoring the firing of sea-launched ballistic missiles (SLBMs). Named the Perimeter Acquisition Vehicle Entry Phased-Array Warning System (PAVE PAWS), the radar has a Soviet counterpart (named Hen Roost by American analysts) by 1978. American and Soviet construction of large phased-array radars between 1977 and the end of the Cold War, in alternation, is a key illustration of buildup in the two countries and in the heightening tensions generally. Although nominally designed for early warning, the radars also can be upgraded for battle management in nuclear war, and as such are sometimes interpreted as violating the Antiballistic Missile Treaty of 1972.

American-Soviet Escalation, 1976-1991

<u>1976</u>

May	The United States and the Soviet Union sign a treaty for peacetime nuclear detonations that limits the size and nature of underground tests.
July	The American spacecraft *Viking I* lands on Mars.
September	Communist Chinese leader Mao Tse-tung dies. ... The United States returns **Eniwetok Atoll** to its original inhabitants. Eniwetok was the site of the first American hydrogen bomb test in autumn 1952.
November	The American people elect Jimmy Carter to the Presidency. His term of office signals a renewed escalation of Cold War actions and counter-actions between the United States and the Soviet Union.

Work toward the MX (Peacekeeper) ICBM continues during the early and middle 1970s, and by mid-decade includes the Multiple Aim Point basing mode. Multiple Aim Point proposes hiding 100 MX missiles in several thousand silos, in a strategy of deception. Missile engineers develop MX to destroy Soviet missiles in their silos. Analysts interpret this weapon as one with first-strike capability, one that would destabilize existing parity.

<u>1977</u>

July	The United Nations admits **Vietnam.**
September	The United States incinerates its last stocks of Agent Orange from the Vietnam War. The project takes place at sea, near **Johnson Island** in the Pacific.

President Carter also supports development of the Tomahawk cruise missile as of this year.

<u>1978</u>

May	President Carter recommends that NATO modernize and augment its military forces. His position marks an end to détente between the United States and the Soviet Union.
September	**Israel** and **Egypt** sign the Camp David Accords at meetings in the United States to discuss the long-term conflict in the Middle East.
December	Tensions in **Iran** escalate and the United States evacuates 900 dependents from Teheran. ... **Communist China** and the United States resume full diplomatic relations.

1979

January	The Shah of **Iran** flees his country. The Ayatollah Khomeini returns from exile the next month to establish a fundamentalist Muslim government.
March	Menachem Begin of **Israel** and Anwar Sadat of **Egypt** sign the Camp David Peace Treaty in Washington, D.C.
June	President Carter approves full-scale development and production of the MX ICBM. ... General Secretary Brezhnev and President Carter sign SALT II to limit long-range bombers and missiles.
July	SAC conducts Global Shield 79, the most comprehensive American nuclear war exercise to date. Global Shield war games continue through the 1980s.
November	**Iran**ian militants seize the American Embassy in Teheran and take 63 hostages.
December	President Carter calls for major American military buildup to counter the Soviet Union. ... The Soviet Union invades **Afghanistan**. ... The United States places sanctions against the Soviet Union in response. Sanctions include a grain embargo, boycott of the Olympic games in Moscow in 1980, refusal to ratify SALT II, and a decrease in scientific and cultural exchanges between the two nations. With regards to SALT II, the United States agrees to abide by its stipulations until 1986. SALT II restricts the modernization of existing weapons systems and places a ceiling on the number of ICBMs allowed with MIRVs. Both the United States and the Soviet Union can undertake only one new ICBM. ... During 1979 and 1980, President Carter considers another basing scheme for the MX: Multiple Protective Shelter. In this mode, 200 MX ICBMs would hide among 4,600 hardened horizontal shelters set alongside 200 oval tracks. ... NATO announces deployment of intermediate-range nuclear forces to counter Soviet SS-20 missiles emplaced under the Warsaw Pact.

1980

January	President Carter labels the **Persian Gulf** a vital American interest.
April	The American Department of Defense orders all **Iran**ian military trainees to leave the United States.
July	President Carter issues Presidential Directive 59. The directive calls for the capacity to wage both limited and protracted nuclear wars.
November	The American people elect Ronald Reagan to the Presidency. Reagan continues aggressive Cold War buildup.

1981

January	**Iran** releases the American hostages.
April	The American space shuttle *Columbia* makes its first trip.
October	**Egypt**ian President Sadat is assassinated. ... President Reagan reverses former President Carter's decision on the B-1 bomber. Reagan announces that the United States Air Force will build and deploy 100 of the advanced aircraft. ... Reagan also decides to deploy the MX in existing Minuteman silos.
November	President Reagan proposes reductions in arms that would eliminate a class of nuclear missiles. His proposal is known as Zero Option and focuses on Soviet IRBMs in **Eastern Europe**. Reagan states that the United States will deploy Pershing and Tomahawk missiles to **Europe** unless an agreement is attainable.
December	After a year of Solidarity leadership in **Poland**, Soviet forces impose martial law.

1982

May	President Reagan outlines a proposal for the Strategic Arms Reduction Treaty (START). The treaty would reduce the number of American and Soviet ICBMs and would devise a verifiable method of reducing the possibility of nuclear war. ... **Spain** joins NATO.
June	START negotiations open in Geneva.
July	USAFE activates the first Tomahawk cruise missiles for Europe.
September	SAC conducts the first operational test of the air-launched cruise missile (ALCM) at Griffiss Air Force Base in New York. The ALCM is the next-generation of missile to augment selected SAC alert wings, and replaces the SRAM.
November	Soviet General Secretary Brezhnev dies. Yuri Andropov succeeds Brezhnev, who had been in power since Khrushchev's removal in 1964.

In 1982, President Reagan proposes Closely Spaced Basing for the MX, a dense-pack scenario where the MIRVs of Soviet SS-24s would destroy each other as they attempted to hit individual American ICBM emplacements. Congress rejects this idea, as it had earlier basing scenarios for the MX under President Carter.

1983

March	President Reagan announces that the United States plans to undertake a space-based antiballistic missile defense system. The Strategic Defense Initiative (SDI), popularly called Star Wars, is interpreted as violating Article V of the Antiballistic Missile Treaty of 1972.
April	The Scowcroft Commission Report calls for modernizing American strategic weapons. The Scowcroft Commission recommends deploying the MX in refurbished Minuteman silos.
May	Congress authorizes procurement of the MX ICBM.
June	By about mid-year, the Soviet Union begins construction of a large phased-array radar at Abalakovo, near Krasnoyarsk above the Mongolian border. This radar, part of the Hen Roost network, is the sixth of its type. The Soviet Union had started the Hen Roost early warning network with a large phased-array radar at Pechora in 1978, and had added four more radars during the early 1980s dispersed along its territorial border. Simultaneously, the United States had continued erecting PAVE PAWS. By 1983, the comparable American network of operational large phased-array radars was five, matching those of the Soviet Union in lock step. These included the radar at Eglin Air Force Base (from 1962-1969), the converted radar from Sentinel / Safeguard (1975), the Cobra Dane intelligence radar in the Aleutians (1972-1977), and the two PAVE PAWS on the east and west coasts of the continental United States. The two countries had started on their sixth large phased-array radars in the early 1980s. For the United States this was a radar at Robins Air Force Base in Georgia, with construction initiated in 1984. As of June, the Soviet Union is slightly in advance of the United States in its construction schedule for the respective radar networks. The Soviet radar at Abalakovo causes an immediate reaction in the United States. Analysts interpret the radar to be a violation of the Antiballistic Missile Treaty. The radar features a number of technical differences from the earlier radars in Hen Roost. It also is sited further within the boundaries of the Soviet Union than allowed under the treaty and is oriented to the interior (and thus can be construed as a battle management radar). ... The United States Air Force launches its first test MX

	at Vandenberg Air Force Base. Its unarmed warheads hit the target area in the **Kwajalein Atoll** in the Pacific.
July	The United States issues a contract for a PAVE PAWS-type radar to replace the radars at the Thule, **Greenland**, BMEWS site. Analysts interpret this action as a violation of the Antiballistic Missile Treaty as well: it represents an upgrading of an existing radar and is sited in a third country, both prohibited by treaty conditions. ... The Soviet Union lifts martial law in **Poland**. ... War between **Iran** and **Iraq** threatens surrounding Arab countries in the **Persian Gulf**. The United States Air Force activates a provisional support squadron at Riyadh Air Base, **Saudi Arabia**.
August	The Soviet Union responds to the United States concerning the Abalakovo radar (usually referenced as the Krasnoyarsk radar), after a formal American complaint to the Standing Consultative Commission for the Antiballistic Missile Treaty in Geneva. ... A terrorist bomb explodes at Hahn Air Base in **West Germany**.
September	The Soviet Union shoots down a **Korea**n commercial airliner over its airspace north of Japan.
October	Terrorists attack the headquarters of the United States Marine Corps in Beirut, **Lebanon**. ... The United States invades **Grenada**, a small Caribbean Socialist country linked to **Cuba** and the Soviet Union.
November	The United States deploys Pershing II and Tomahawk missiles in **West Germany**.
December	The Soviet Union suspends its participation in START talks. ... Late in the year, the United States Air Force awards the contract for the large phased-array radar at Robins Air Force Base, the third PAVE PAWS. This radar, like that at Abalakovo, is sited further inland than allowed under the Antiballistic Missile Treaty.

The year 1983 begins what analysts of international politics call "breakout" from the Antiballistic Missile Treaty—by both the United States and the Soviet Union. The situation with the large phased-array radars and Reagan's SDI, in particular, mark a significant escalation in Cold War tensions.

<u>1984</u>

February	American Marines withdraw from **Lebanon**. ... General Secretary Andropov dies. Konstantin Chernenko, Brezhnev's chief of staff, succeeds him.
April	Construction begins on the third PAVE PAWS at Robins Air Force Base in Georgia.
September	Terrorists bomb the United States Embassy in Beirut, **Lebanon**. ... President Reagan proposes a broad framework for renewed arms talks between the United States and the Soviet Union.
November	The United States and the Soviet Union agree to return to negotiations on nuclear and space arms issues.

<u>1985</u>

March	Mikhail Gorbachev succeeds General Secretary Chernenko. Both Andropov's and Chernenko's terms were very short and contributed to the instability of the early 1980s. Both men had died in office. Gorbachev marks a new era in Moscow leadership, one that will be characterized by less anti-Western sentiment. ... Nuclear and Space Talks open in Geneva and derive from the START negotiations of 1983.
June	The United States Air Force conducts the final test launch of the MX at Vandenberg Air Force Base.
July	SAC accepts the first B1-B bomber and makes it operational at Dyess Air Force Base in Texas.

September — The Soviet Union presents a proposal for START that includes the idea of deep reductions in strategic offensive forces.

November — The United States submits a counterproposal at the START talks. At the Geneva Summit later in the month, President Reagan and General Secretary Gorbachev issue a joint statement that features a 50% reduction in nuclear arms for both countries.

<u>1986</u>

January — General Secretary Gorbachev proposes eliminating all nuclear arms within 15 years, contingent on the United States ceasing R&D toward SDI. President Reagan sustains his position of late 1985 toward a 50% reduction in arms and continues to support SDI. ... The space shuttle *Challenger* suffers a catastrophic accident that kills all aboard.

April — Terrorist acts occur against the United States in **Libya**. The United States launches a retaliatory air strike. ... An explosion and fire at a nuclear power plant in Chernobyl spreads radiation over a large area in the Soviet Union. A near core melt down at the Three Mile Island nuclear power plant in Pennsylvania in March 1979 had not gone critical, but had suggested a similar scenario years earlier in the United States.

October — President Reagan and General Secretary Gorbachov meet at the Reykjavik Summit to continue arms discussions. Talks stall due to Reagan's continued stance on SDI.

November — The Iran-Contra scandal begins to be uncovered. The United States had sold arms to **Iran** and used the proceeds to finance a rebellion in Nicaragua.

December — At the end of the year, the Soviet SS-24, a 10-MIRV ICBM comparable to the MX, becomes operational. The Soviet Union deploys the SS-24 in a rail-mobile configuration, rather than in fixed silos, an action that again ups the stakes during the late Cold War. Simultaneously, SAC places the 10th MX on alert at F.E. Warren Air Force Base in Wyoming in a modified Minuteman silo. President Reagan announces the United States intentions to design and construct a garrisoned, rail-mobile basing system for the MX. The United States Air Force renames the MX as the Peacekeeper. Both the United States and the Soviet Union also develop a road-mobile small ICBM at this time.

<u>1987</u>

January — General Secretary Gorbachov addresses the people of the Soviet Union on the nuclear arms race. President Reagan also speaks to the Soviet citizenry via the Voice of America.

August — The United States Air Force awards the contract for Peacekeeper Rail Garrison to Boeing. ... **West Germany** states that it will destroy its Pershing missiles if the Soviet Union and the United States also destroy IRBMs in the region.

September — The United States and the Soviet Union sign the Nuclear Risk Reduction Center Agreement to begin improved communication and build confidence between the two nations. ... Following a formal vote in the United States Congress on the large phased-array radar at Abalakovo (the Krasnoyarsk controversy that dated to mid-1983), the Soviet Union allows an American diplomatic group to visit the radar. The Abalakovo radar is still under construction, but is approaching operational status.

December — President Reagan and General Secretary Gorbachov meet at the Washington Summit and agree to eliminate IRBMs and continue work toward START. Reagan and Gorbachov formalize the pact as the Intermediate-Range Nuclear Forces Treaty. The United States agrees to remove Pershing II and Tomahawk missiles from **Europe**. In

counterpoint, the Soviet Union agrees to remove its installations of SS-20 IRBMs in **Eastern Europe.**

During the year, the United States Congress votes to deny air defense spending for projects that violate a traditional interpretation of the Antiballistic Missile Treaty of 1972. The SDI project falls within this category.

1988

January	The United States and the Soviet Union resume Nuclear and Space Talks of March 1985 in Geneva. The discussions move toward a joint draft of START.
April	The Soviet Union agrees to remove its military forces from **Afghanistan** by early 1989, after seven years of talks toward this goal. ... United States Navy aircraft attack **Iranian** warships and offshore oil platforms in the **Persian Gulf**. ... The United States Air Force begins delivery of sensitive verification equipment for monitoring nuclear arms tests to the Republic of **Kazakhstan** within the Soviet Union. The event is a first and delivery efforts continue into July.
May-June	President Reagan and General Secretary Gorbachov meet at the Moscow Summit and state their continued commitment to START.
June	General Secretary Gorbachov announces Glasnost, a proposal for a more relaxed Soviet society with progressive Socialist doctrine.
July	The United States Navy shoots down a commercial **Iran**ian airliner during continued heightening tensions in the Middle East.
August	Solidarity strikes occur in **Poland**.
September	The American space shuttle *Discovery* launches without incident, ending the nearly three-year stand-down of the manned space program in the United States.
November	The first B-2 Stealth bomber rolls out at Air Force Plant 42 in Palmdale, California.
December	The United States sends disaster relief supplies to the Soviet Union over an eight-week period following a major earthquake in **Armenia**. The operation marks a turning point in American-Soviet relations and is the first time that the Soviet Union permits American flights to its cities without Soviet observers on board.

In 1988, construction of the prototype test site for Peacekeeper Rail Garrison is underway at Vandenberg Air Force Base in California. The installation uses elements of infrastructure previously built for testing the MX during the late 1970s and early 1980s.

1989

April	**Poland** agrees to legalize the Solidarity Union. ... Pro-Democracy demonstrations occur in Beijing, **China**.
May	General Secretary Gorbachov visits Beijing to normalize relations between the Soviet Union and **China**.
June	The Chinese Army attacks protesting students in Tienanmen Square in Beijing. ... The United States Air Force flies medical supplies and personnel to the Soviet Union after a major accident on the Trans-Siberian Railroad southeast of Moscow. About 850 passengers are killed or injured.
September	The United States and the Soviet Union sign the Reciprocal Advance Notice of Major Strategic Exercises Agreement to prevent accidental war driven by misinterpreted military activity. ... Beginning this month, **Eastern Europe**an nations leave the Soviet Bloc and renounce ties to Moscow. Government regimes begin to change in several nations.

November	**East Germany** opens the Berlin Wall allowing unrestricted visitation to West Berlin for the first time since 1961. The event is subsequently known as ***the Fall of the Berlin Wall and is one milestone that historians interpret as ending the Cold War.***
December	At the Malta Summit, President Bush pushes for an acceleration in START negotiations.

<u>1990</u>

February	Marxist rule in **Nicaragua** ends.
March	The people of **East Germany** vote for a reunified Germany and a market-based economy.
April	The United States Air Force removes the first missile from Europe for destruction in accordance with the Intermediate-Range Nuclear Forces Treaty of late 1987.
May-June	President George Bush and General Secretary Gorbachov attend a summit meeting in Washington, D.C.
July	SAC takes Looking Glass off continuous airborne alert. Looking Glass EC-135s had functioned as airborne nuclear command and control posts for nearly 30 years and had logged over 250 million hours of flying time.
August	**Iraq** invades **Kuwait**. Operation Desert Shield begins to protect Saudi Arabia and to buildup up an American-allied military presence.
October	East and West **Germany** reunite as a single country.
November	The Treaty of Conventional Armed Forces in Europe cuts East-West land armies.
December	Construction for Peacekeeper Rail Garrison is nearly complete at Vandenberg Air Force Base. ... The Polish people elect Lech Walesa as President.

<u>1991</u>

January	The Gulf War begins in the **Persian Gulf**. The United States and an international coalition attack **Iraq**.
March	**Iraq** accepts cease-fire terms, ending the Gulf War.
July	President Bush and General Secretary Gorbachov sign START. The treaty pledges that both countries will reduce their nuclear arsenals by 50% and will eliminate all MIRVed ICBMs by the close of 1992. The Peacekeeper ICBM, with its 10 independently-targetable warheads is included in START and its advanced basing scheme, Rail Garrison, is a treaty bargaining chip. ***Historians also acknowledge the signing of START as the formal end of the Cold War.***
August	A coup fails in the Soviet Union against General Secretary Gorbachov, but foreshadows the dissolution of the country into the ethnic regions that preexisted the rise of Communism. Power in the Soviet Union shifts to Russian President Boris Yeltsin.
September	***The American Senate votes* 67 to 33 *to cancel* the Peacekeeper *Rail Garrison* program. ... *SAC takes all bombers, tankers, and Minuteman IIs off alert*** by order of President Bush late in the month. SAC had maintained aircraft on alert continuously since October 1957. Only Minuteman IIIs, the Peacekeeper, and the Navy's sea-launched ballistic missiles remain on alert as of this date. ***Political and military historians also interpret these actions as symbolic ends to the Cold War.***
October	President Bush and General Secretary Gorbachov agree to major unilateral cuts in nuclear arms. ... The United States Air Force continues to airlift relief supplies to the Soviet Union.
December	The Commonwealth of Independent States replaces the Soviet Union. General Secretary Gorbachov resigns and control of the former Soviet Union's nuclear

arsenal passes to Russian President Yeltsin. ***The United States recognizes Armenia, Belorussia, Kazakhstan, Kirghizia, Russia, and the Ukraine in the beginnings of the geopolitical redefinition of the Eurasian region. This sequence of events also marks the end of the Cold War.***

Part II: From Air Materiel Command to Air Force Materiel Command, 1907-1992

Antecedents and Issues through World War II

Beginnings of a Command Mission

From the earliest days of American aircraft development, the United States Army realized that aviation would define key achievements in war and peace. By 1907, the Army's Chief Signal Office had inaugurated its aeronautical division as a formal research arm. American military aeronautical research and development, more commonly known as R&D, received federal monies approaching half a million dollars over the next five years. The large infusion of funding and interest, however, was far less than that in much of the industrialized world during the same period. Manned flight, and all that such accomplishment implied, was a keen priority of Germany, in particular. By 1913, Germany—on the eve of the first world war—had spent $64 for each American dollar allocated for military aeronautical R&D. In northern Europe, Belgium also exceeded American expenditures toward aeronautical research, while Britain too moved ahead. In southern Europe, Bulgaria, Italy, Spain, and Greece all concentrated on military flight, with Brazil precocious in its sphere of influence in South America. Even in Asia, Japan and China outspent the United States on military aeronautical research.[1] One example of concentrated aeronautical progress at an early date, in both Europe and the United States, was that of aero-medicine. The French military began evacuating its wounded troops, as well as those of its Serbian allies, by aircraft from the Albanian mountains in 1915. By 1917-1918, the United States Army focused parallel experimentation on the Curtis JN-4, placing ambulance aircraft at a nucleus of installations that included McCook Field in Dayton, Ohio, and, Brooks Field in San Antonio, Texas. Both of these locations are associated with installations (Wright-Patterson and Brooks Air Force Bases) that would become prominent in aeromedical studies and would continue to evolve into the present Air Force Materiel Command (AFMC).[2]

European advancements in aeronautical research, as well as a difficult American relationship with neighboring Mexico and the outbreak of war in Europe, had prompted Congress to fund the National Advisory Committee for Aeronautics (NACA) in 1915. Simultaneously, Congress also had infused more monies into military aeronautics through appropriations for an Aviation Section within the Signal Corps. NACA became established as the center for theoretical aeronautical research and achieved its first infrastructure at Langley Field, Virginia, just after World War I. The Army's Signal Corps assigned its experimental aeronautical work to a different location, establishing McCook Field in Dayton during 1917 for the purpose of applied aircraft research. The Signal Corps had responded directly to American entry into the first world war and, not surprisingly, had moved more quickly than NACA. Initially named North Field, McCook was modest in size, built as a temporary installation to meet wartime needs. From 1917 forward, however, the Army—and subsequently the Air Force—undertook continuous research, development, testing, and evaluation of prototype aircraft, including their full catalogue of respective parts and attached weaponry. The Signal Corps created its Airplane Engineering Department at McCook, alternately known as the Signal Corps Experimental Laboratory, to take theoretical contributions achieved at other venues and apply them to perceived military requirements. The McCook laboratory employed approximately 1,400 scientists and engineers when it opened in 1917, a number that climbed to 2,300 by the close of World War I (including technicians and support officers).[3] The Signal Corps augmented its flight tests at McCook with additional efforts at the nearby Wilbur Wright Field, an airfield established in June 1917 for training Army pilots at the Signal Corps Aviation School.[4] As of mid-1919, the Signal Corps consolidated the experimental aircraft mission at McCook and transferred certain activities from NACA's oversight at Langley to the Ohio location.[5] The Army created its Air Service branch following the first world war, shifting the aviation development mission from the Signal Corps,

generally, to the Air Service tiered within the Corps. Simultaneously, the Army upgraded McCook's Airplane Engineering Department to a division. The Air Service further divided the Engineering Division into tasked sections focused on the "technical development of aircraft, armaments, engines, equipment, and materials."[6] McCook's facilities continued to feature two short runways, one sod and one macadam-and-cinder.

From the very beginning, applied aeronautical research and development became linked to a military supply, repair and upgrade mission. The Signal Corps Equipment Division, in Washington, D.C., orchestrated a depot function "to receive, store, and issue equipment and supplies to the Signal Corps' aviation, mechanic, and armorer schools." In the Dayton area, the Signal Corps built the Fairfield Aviation General Supply Depot (the precursor of Patterson Field) in the autumn of 1917 to complement both McCook and Wilbur Wright Fields.[7] The Army established three other primary supply installations as air depots during 1917-1918, including ones at Harrisburg, Pennsylvania (Olmsted Air Force Base, closed in the late 1960s); San Antonio (Kelly Air Force Base, closed in 2001); and, San Diego, California (Rockwell Field, today a part of the Naval Air Station at North Island).[8] The air depot system of World War I initiated a division of the continental United States into geographically defined Air Materiel Areas (AMAs).

Between the Wars

In 1926, Congress passed the Air Corps Act and in October that year, the Air Corps established three major activities for its command. One of these, the Materiel Division, consolidated functions within the Engineering, Supply, and Industrial War Plans Divisions of the Air Service. Within the overall hierarchy of the Materiel Division, the Air Corps continued to develop air depots. In addition to the four in the continental United States, the Air Corps established depots in Panama, Hawaii, and the Philippines in June 1927. Minor depots also went in place in Little Rock, Arkansas, and at Scott Field, Illinois, but these depots closed in the early 1930s. (In Little Rock, the Air Force established a subsequent installation in the middle 1950s, Little Rock Air Force Base. Scott Field evolved directly into Scott Air Force Base.) As of 1934, planning was underway for an additional major continental depot at Mobile, Alabama (to become Brookley Air Force Base, now closed). By the end of the decade, Rockwell Air Depot had also ceased activity, with the function moved to a new air depot under construction in Sacramento, California, at McClellan Field. The relocation to Sacramento followed the Army's leave-taking of North Island and the Navy's emergence there. (McClellan Air Force Base closed in 2001.) As the United States sat on the eve of World War II in late 1940, yet another major air depot was under construction at Ogden, Utah (today's Hill Air Force Base)—taking the Air Corps depots to a total of six in continental United States. East to west these depots served the Middletown, Fairfield, Mobile, San Antonio, Ogden, and Sacramento AMAs, physically located in Pennsylvania, Ohio, Alabama, Texas, Utah, and California.[9]

Aeronautical advancements between the first and second world wars slowed within the United States Army, with a federal aviation R&D budget that climbed no higher than four million dollars annually between the years of 1925 and 1937, and sank at times to as little as two million dollars during the period. Yet, the numbers were somewhat deceptive. As of the late 1930s, American industry funded aeronautical research at almost $100 million annually, while NACA distributed 30 major grants to universities.[10] With regards to the design and engineering of buildings and structures tied to advancements in aircraft and air weapons systems, work going forward in Germany also benefited efforts in the United States. Not surprisingly, German aeronautical scientists and engineers made marked strides after the rise of the National Socialist Party in 1934 and the state-backed endeavors thereafter. Less well known, in the United States corollary achievements of immigrant civil engineers from Germany, Austria, and Czechoslovakia are notable for aviation structures, from the middle 1920s forward. In one situation, parallel to that of Project Paperclip following World War II, the

United States Navy Bureau of Aeronautics brought 12 German engineers to Akron, Ohio, in 1924 to lead the development and manufacture of dirigibles for Goodyear-Zeppelin, a subsidiary of Goodyear Tire and Rubber Company. Dr. Karl Arnstein, a renowned engineer from Prague who had advanced within firms in Switzerland, France, and Germany between 1909 and World War I, had orchestrated the achievements in the design and engineering of aluminum dirigibles for Luftschiffbau-Zeppelin after 1913 and had been among the first to design and construct a metal observation plane toward the end of the war. Zeppelin manufactured airships for the German military, and afterwards the Allies received the dirigibles as spoils of the conflict. Dr. Arnstein led the German engineers who came to Akron, much as Wernher von Braun headed the Paperclip rocket scientists at the Redstone Arsenal in Huntsville, Alabama, as of 1950. Arnstein's group designed not only dirigibles for the United States Navy, but also a 1175-foot long steel hangar for Goodyear in 1929.[11] The Engineering Division of the Air Corps in Dayton, physically sited only a few hours to the south of the Navy's Bureau of Aeronautics enterprise at Goodyear in Akron, must have been well aware of the work of its R&D neighbor.

Also as of the middle 1920s, two other Viennese engineers, John E. Kalinka and Anton Tedesko, immigrated to Chicago to work for the engineering firm Roberts & Schaefer. Both men had previously been employed with the German firm Dyckerhoff & Widmann in Wiesbaden-Biebrich. Dyckerhoff & Widmann pioneered reinforced concrete construction and had continuously tested thin-shell, barrel-vault and domed structures after 1922, focused through the efforts of engineers Franz Dischinger and Ulrich Finsterwalder. The firm's first major commission had been for the Zeiss optical company, from whence derived the later patented name for the thin-shell system, Z-D (Zeiss-Dywidag [Zeiss - Dyckerhoff & Widmann Aktien Gesellschaft]).[12] Dyckerhoff & Widmann built thin-shell industrial structures throughout Germany, Lithuania, Rumania, Hungary, Belgium, and Italy during the 1920s, designing aircraft hangars for the German military during World War II. John Kalinka hired with Roberts & Schaefer in 1925. Tedesko followed him to the firm in 1932, having previously worked in the United States from 1926-1928 and in Germany for Dykerhoff & Widmann from 1930-1932. Tedesko became a premier engineer in his own right after immigration to the United States. Drs. Tedesko and Kalinka maintained an active professional exchange with engineers at Dykerhoff & Widmann, and had the assignment to market Z-D long (longitudinal)-barrel, short-barrel, and domed construction in the United States through a patent-like agreement between Dykerhoff & Widmann and Roberts & Schaefer. All of the American engineering journals began publishing articles on the innovative construction technology as of 1929, including *Engineering News-Record*, *Western Construction News*, *Construction Methods*, and *Transactions of the American Society of Civil Engineers*. Dykerhoff & Widmann interpreted Z-D as particularly appropriate for industrial buildings and hangars, and the firm targeted the American military as a key potential client as of the early 1930s.

By late 1932, correspondence between Roberts & Schaefer and Dykerhoff & Widmann, in German, discussed proposed military airfield shops in Portland, Oregon. The two firms sketched these shops as long-barrel in type, with their design closely resembling that of shops built at Wright Field at the outset of the 1940s (today's Building 20005 in Area B). In late 1934, Roberts & Schaefer won the contract for the German Pavilion built for the second season of the Century of Progress World's Fair in Chicago. Other key commissions showcasing Z-D went forward in the United States during the later 1930s in Illinois, Kansas, Wisconsin, Tennessee, Louisiana, Mississippi, Pennsylvania, New York, and Washington, D.C. As of July 1939, correspondence concerning the details of the Dykerhoff & Widmann and Roberts & Schaefer Z-D seaplane hangars for the Navy at North Island—the former Rockwell Air Depot in San Diego—was in progress. As of 1940, Tedesko was actively designing industrial warehouses, engineering shops, and hangars for the Army at Wright Field and at materiel storage sites in Ohio, with work at air depots yet to come. At nearby Vandalia, the site of today's Dayton Airport, Tedesko designed eight laminated timber arch hangars for an Army

modification center (today gone). The engineering profession interpreted the Vandalia clear spans as the longest achieved in laminated wood anywhere, each at a 177-foot span 57 feet high (see Plate 187 in Volume II).[13] The Army warehouse complex in Columbus, Ohio, underway in 1941, showcased not just a major technological innovation, but also an exponential leap in size and a radically new speed of construction. Contractors erected the first of the four quarter-mile warehouses at the site in just 36 days.[14] The Army's Gentile warehouse complex in Dayton was equally futuristic (see Plate 186 in Volume II).

From the late 1930s, then, the organization that would ultimately become AFMC demonstrated a special interest in innovative construction to meet the needs of the command and the future Air Force—turning first to German structural engineering expertise.[15] Anton Tedesko filled a prominent role for the Army Air Forces during World War II and for the Air Force during the late 1940s. From 1955 to 1970, he worked as a direct consultant to Headquarters Air Force "as a troubleshooter and in decisions leading to innovative solutions for new construction and renovation." Beginning in the 1950s, he designed and engineered sophisticated domed underground launch control facilities for missiles testing through the Air Force Ballistic Missile Division (AFBMD) in Los Angeles (see Volume II, Chapter 9). Tedesko was immediately behind the scenes in the basic plans and engineering for Minuteman ground support equipment, including underground launch control centers built at operational sites, and of training facilities at Vandenberg and Chanute Air Force Bases in California and Illinois, respectively (see Volume II, Chapter 6). In 1961-1962, Tedesko designed the 200-foot rail-retractable, steel-truss gantry at Canaveral's Launch Complex 36 for the Atlas-Centaur vehicle (at Cape Canaveral Air Force Station, supported by Patrick Air Force Base, Florida)—a launch complex vital to the space program throughout the Cold War (Plate 1). Also directly supervised through the AFBMD, the design and engineering of Launch Complex 36 was recognized in the international engineering community as a major achievement.[16] As of 1962 also, he was one of a four-member team of multidisciplinary consultants working for the National Aeronautics and Space Administration (NASA) on the design and engineering of Launch Complex 39, also at Canaveral. The complex stood 48 stories tall and accommodated launch of the manned Apollo lunar spacecraft. The NASA engineering and design team was that of URSAM, set up by Anton Tedesko and Max. O. Urbahn. URSAM was a composite group formed from the talents of four companies, one that created an acronym from its members' names: Max O. Urban (architect), Roberts & Schaefer (structural engineering), Seelye, Stevenson, Value & Knecht (civil, mechanical, and electrical engineering), and Moran, Proctor, Muser & Rutledge (foundations engineering). The Vertical Assembly Building and Launch Control Center designed for Launch Complex 39 each took major awards, in engineering and architecture, during 1965 and 1966.[17]

The Army's management hub for both aeronautical R&D and depot supply had also continued to evolve during the 1920s and 1930s, with Dayton remaining the center of activities. With demobilization after World War I, Wilbur Wright Field, the Air Service Armorer's School, and the Fairfield Depot merged to become the Wilbur Wright Air Service Depot (still most often referenced as the Fairfield Air Depot). The Army acknowledged McCook Field as too small and locationally challenged by encroaching population growth. Desiring to sustain the physical site of the Air Service's Engineering Division, a locally formed group—the Dayton Air Service Committee—bought just over 4,500 acres to the northeast of the town and gave the land to the United States government. The site included the previously leased Wilbur Wright Field, allowing the War Department to annex the adjoining Fairfield Air Depot to the new acreage as Wright Field. Construction of engineering facilities at Wright Field was underway in early 1926. Wright Field became the headquarters location of the Materiel Division of the Air Corps, and thus the administrative center for the air depot program, even as it also replaced McCook Field and became the headquarters site for Army, and subsequently Air Force, aeronautical engineering.[18]

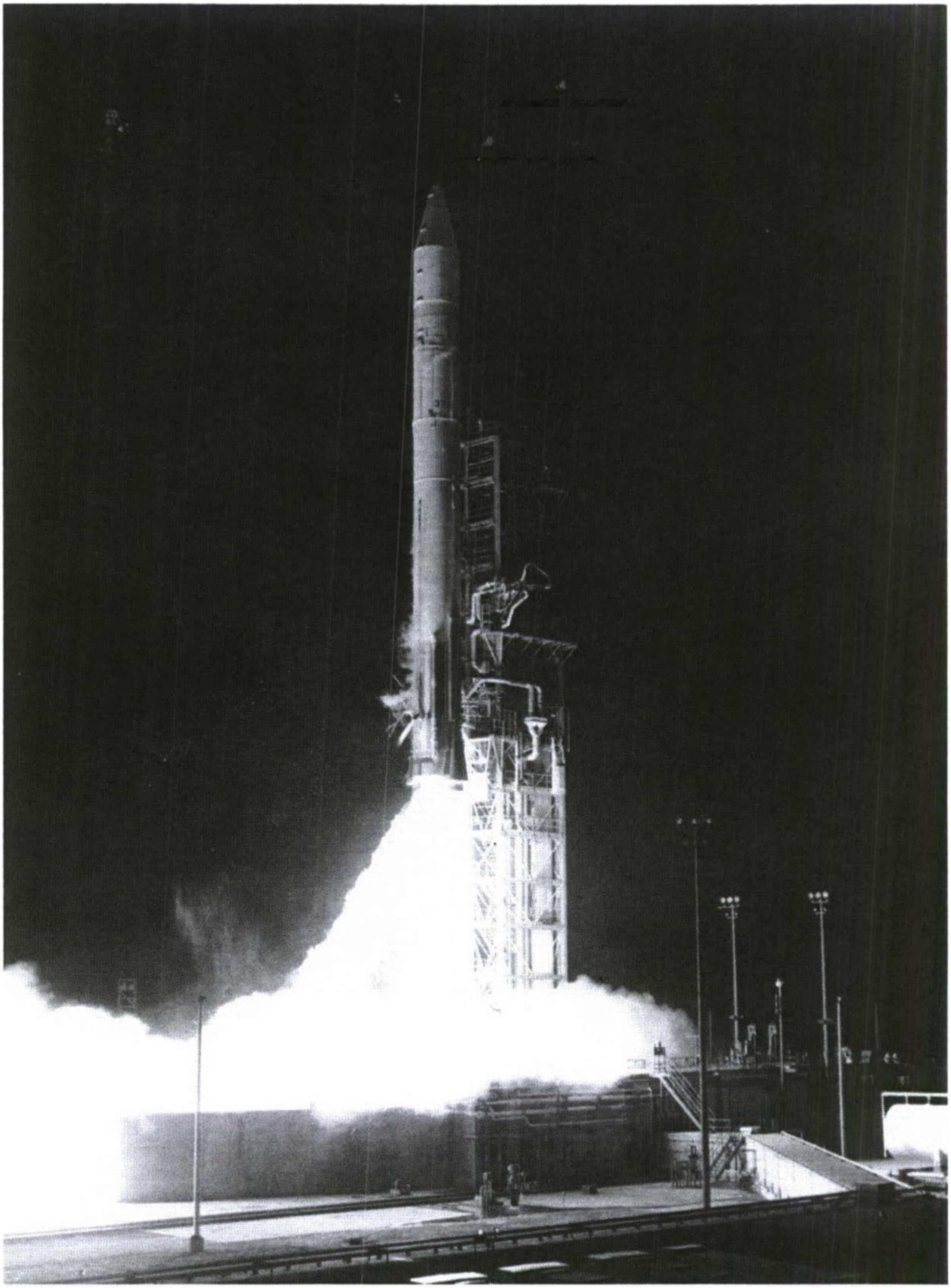

Plate 1: **Anton Tedesko (Roberts & Schaefer). Moveable Launch Tower for the Atlas-Centaur Space Vehicle, Launch Complex 36, Cape Canaveral, 1961-1962. Boost of the Intelsat IV-A into synchronous orbit over the Atlantic Ocean, 26 January 1976. In *History of the Air Force Eastern Test Range 1 January –31 December 1976.***

By the middle 1920s as Wright Field unfolded, the Army's aeronautical materiel mission had already become daunting in its size and futuristic in its vision. The military service arm captured the breadth of meaning that its Air Corps intended for "materiel" in the bracketing shields adorning the Materiel Division's administration headquarters building at the new Wright Field. Each shield featured an interpretation of Auguste Rodin's *The Thinker*, an internationally known French bronze sculpture of 1880 that had been cast as a free-standing piece, and more notably was the central figure in another Rodin work, *Gates of Hell*. The latter commission was for the entrance to a Paris museum, based on scenes from Dante's *Inferno* and unfinished at Rodin's death in 1917. The first bronze casting of the *Gates of Hell* portal, an 18- by 12-foot work, occurred in the late 1920s—simultaneously with the use of *The Thinker* in the Materiel Division shield at Wright Field. *The Thinker* sits in judgment atop the *Gates of Hell*, above writhing figures in the afterlife. An intellectualized humanity replaces traditional Christian imagery and makes man his own god. One could extrapolate further, that man as scientist-creator (rather than as artist-creator) was newly empowered in the modern age. The small Materiel Division shields, with *The Thinker* contemplating a winged globe held in his right hand, pointed to the significance of the future, of science itself, and to the emerging military command.

During the 1930s, Wright Field solidified the Dayton area's early reputation as the American aeronautical engineering center. Engineers developed experimental, prototype, and production aircraft, and began marketing aircraft to foreign nations as well as to the military services in the United States. Improvements were a constant, ranging from uses of newly derived synthetic materials and advanced devices, to testing under all conceived conditions. Laboratory research also initiated a more concentrated study of the biomedical and physiological issues associated with high altitudes and flight. Efforts on the supply side of materiel also went forward during the decade. As would be true over time, the R&D and depot functions of the command—and of the installation at Wright Field—were uneasy in their compatibility. In mid-1931, the Air Corps again separated aeronautical engineering laboratories and test facilities from industrialized warehouses, shops, and maintenance hangars, designating the original Wilbur Wright Field, the Fairfield Depot, and the Wright brothers' flying field on Huffman Prairie as a distinct installation, Patterson Field. With rapidly deteriorating conditions in Europe by 1939, Congress authorized expenditures of $300 million to build a 5,500-aircraft military arm—seeking to catch up with the flight advancements of its potential allies and enemies. In mid-1941, the Air Corps became the Army Air Forces, the result of a continuous movement within the Army to make its military air arm an independent entity.[19]

World War II

The World War II years intensified growth of an air materiel command, and greatly expanded physical facilities at both Wright and Patterson Fields, foreshadowing specific infrastructural issues that would become paramount after 1945. During the war, the workforce supporting the military installations in the Dayton area jumped in size more than 12 times, with new construction equally dramatic. In 1941, the Army Air Forces designated two commands at Wright and Patterson Fields. The Materiel Division of the former Air Corps became Materiel Command in 1942, and the logistics mission of the supply depot at Patterson Field formally moved under Air Service Command. Confusion in separating the two airfields and their functions continued through World War II, with both Materiel and Air Service Commands deactivated in 1944 and replaced by Air Technical Service Command—a single command paralleling the original Materiel Division of the Air Corps. Aeronautical research at Wright Field continued progress made during the 1930s, with an emphasis on procurement needs. Personnel at Wright Field also stepped up interpretation of enemy aircraft and flight vehicles, as well as the analysis of written documentation of foreign technologies. Wright Field oversaw aircraft procurement and production in general, with strong ties to the military contracting world and with a transition from piecemeal business practices to mass production, using off-the-shelf procurement for parts and assemblies. Aircraft and weapons testing for more basic R&D at Wright

Field also forged ties to the new Air Proving Ground sited at Eglin Field in the Florida panhandle. Eglin provided 10 airfields and over 700 square miles of associated test ranges.

Early in World War II, Air Service Command oversaw its supply mission somewhat haphazardly, akin to the unclear jurisdictions at Wright and Patterson Fields. Before mid-1942, both Air Service Areas and Depot Control Areas defined depot sectors, and each had geographic boundaries that overlapped egregiously. Not until late May did Air Service Command move toward consolidation, achieving a stronger correlation between regions and depots at the close of the year. The newly organized jurisdictions were formally termed Air Service Areas, with their managing depots referenced as Air Service Centers. Along with the overall structural changes came subdepots; specialized storage; district petroleum offices; and intransit depots. The Army Air Forces initiated a specialized storage program with the establishment of Specialized Depots in May 1943. These depots operated similarly to the major Air Depots, but did not include maintenance and repair activities. Specialized Depots stored one or more classes of spare parts, equipment, and supplies. During early 1944, Air Service Command sustained 36 airfields and stations, with a training center in Fresno, California.[20] In Ohio, Patterson Field became a major supply depot and logistics center for the Army Air Forces, overseeing an additional 21 storage depots, 16 subdepots, and 11 detachments in the Midwest—including ones for servicing as well as air depot, air cargo, and overhaul functions.[21] Elsewhere in the continental United States, the supply and logistics mission expanded from the six major air materiel centers (Air Depots) sited at Patterson Field and in Harrisburg (Middletown), Mobile, San Antonio, Ogden, and Sacramento, to a total of 12. During the war, the Army Air Forces added centers at Rome, New York (1942); Warner Robins, Georgia (1942); Oklahoma City, Oklahoma (1942); San Bernardino, California (1942); Spokane, Washington (1942); and, Miami, Florida (1944)—the first five of these centers evolving as Griffiss, Robins, Tinker, Norton, and Fairchild Air Force Bases. The 11 major centers each supported an identifiable acronym that would set the pattern for the post-World War II period[22] (Plate 2). The Miami depot, the last of the group, was unusual in that it did not have responsibilities linked to its host region, but instead served as the principal shipping point for supplies to the Caribbean.[23] The complete picture of the Army Air Forces air materiel mission in mid-1945 included 14 major locations in the continental United States, with additional cold weather testing in Alaska at Ladd Field (1940) and in Michigan at the Oscoda Bombing and Gunnery Range (by 1939).[24]

A New Approach to Infrastructure

During the 1940-1945 period, too, the Army Air Forces Materiel and Air Service Commands, followed by its Air Technical Service Command, sponsored several key commissions for innovative infrastructure that continued to link a nascent air materiel command to provocative civil engineering. Problem sets of these six years addressed the primary challenges of large, clear-span hangar interiors; the basic choices between reinforced concrete or steel for such structures; and, the need for significant redesign and engineering of runways for oversized, heavy aircraft. The critical stimuli for the infrastructure emerging in 1945 were advanced bombers, both those operational and those in design. Hangars for the B-29, as well as runway and hardstand pavement, led directly to those for the B-36. The Army Air Force's usage of the B-29, its modification of the B-29 as the B-50, and the long development for the B-36, caused a leap-frogging of civil engineering achievements for required structures at key installations. Production and upgrading of the B-29, coupled with intense anticipation for the testing and evaluation needs of the B-36, also meant that certain airfields under Army Air Forces Materiel and Air Service Commands were the very first to host the emerging flightline landscape. R&D-type missions, and those of depot-sponsored modification and supply transport, supported the changes. The result is physically evident across the historic bases of AFMC, more than at those of other commands within the Air Force. The architects and engineers responsible

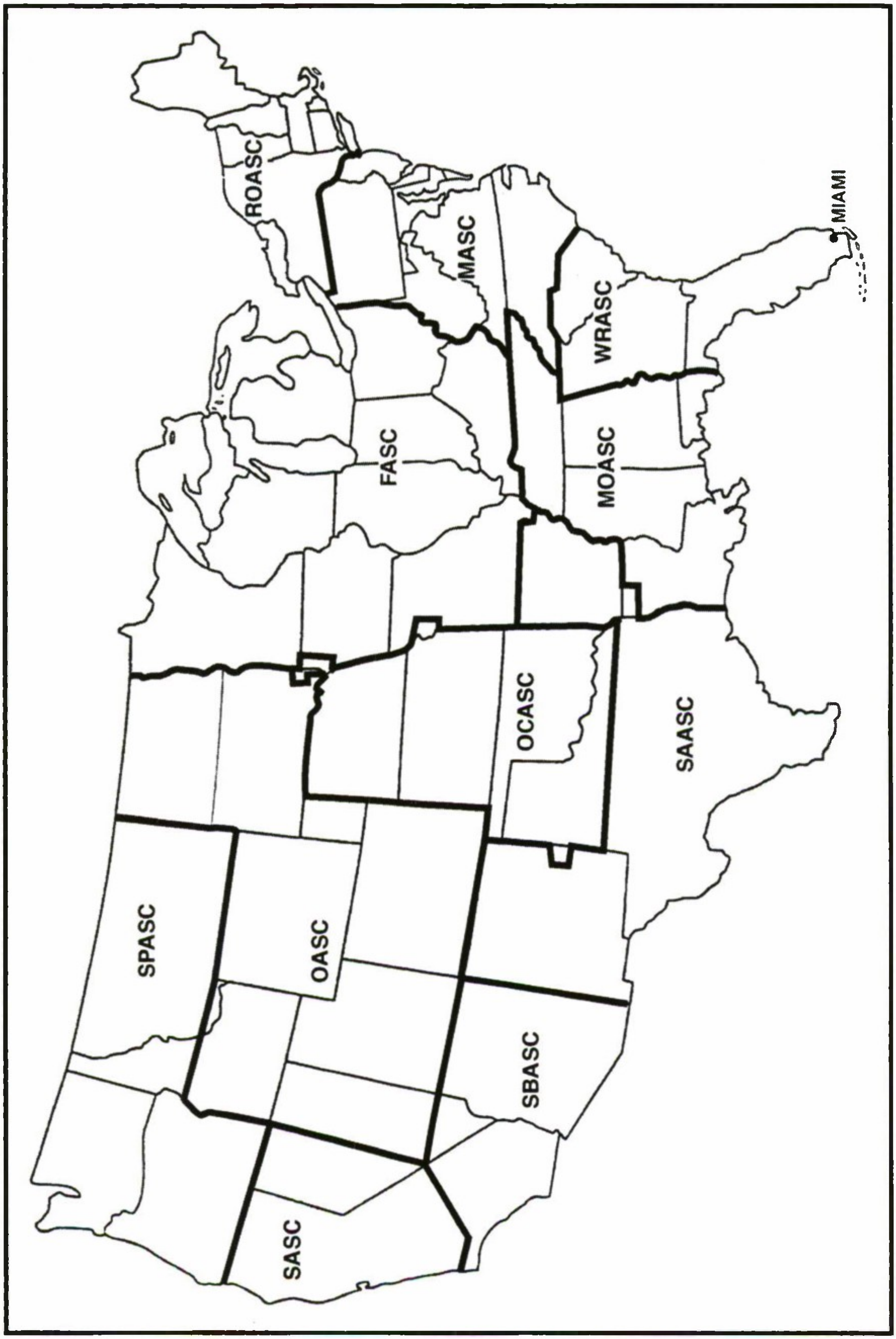

Plate 2: Air Service Command. Air Service Areas, 15 April 1944. Boundaries of ASCs in this period were unusually irregular. Adapted from *History of the Army Air Forces Air Service Command 1921 – 1944*, volume 1, August 1945.

for designing the earliest maintenance hangars for the B-36, in particular, are of an international stature—both in their own lifetimes and as understood today.

As of 1940, the Army tested and showcased the reinforced concrete-versus-steel dilemma at both Wright and Patterson Fields through the cutting-edge work of engineers Anton Tedesko and Albert Kahn. The Army commissioned no less than three major Tedesko buildings at Wright Field: a five-bay, long-barrel hangar; multiple-bay, short-barrel engineering shops; and, a short-barrel hangar for the Signal Corps. These thin-shell structures were in addition to the Z-D warehouses in Dayton and Columbus. The entire Tedesko grouping of Z-D buildings in Ohio was the most concentrated of its type anywhere in the world (Plates 3-4). By May 1947, Tedesko (for Roberts & Schaefer) would design the first full-scale maintenance hangar for the B-36, again of thin-shell Z-D construction. The Air Force planned that hangar, erected at two installations for Strategic Air Command (SAC), as one of the key structures for the bomber during its earliest arrival in military inventory. Notably, in 1947 Air Materiel Command also anticipated one three-bay, and one two-bay, hangar of just this type for the B-36, intending to site the hangar along the flightline at Patterson Field. Although never built, the Patterson Field hangars would have made the Tedesko cluster of Z-D construction even more remarkable. (See Volume II, Chapter 14).

The counterpoint steel hangar destined for B-36 consideration derived from Albert Kahn's Transport Squadron Hangar of 1940. A steel-truss hangar erected at installations in single and double units, the Transport Squadron Hangar went in place at the Ogden (Hill) depot as a single hangar, and as double hangars at Wright Field and at the depots of San Antonio (Kelly); Warner Robins (Robins); Rome (the former Griffiss); and, Oklahoma City (Tinker). The double hangars featured a connecting administrative office, with open courtyard.[25] Each of the double hangars was also an improved version of the Kahn original, with collaborative efforts by Norwegian engineer Fred Severud. While Kahn and his Detroit firm had been responsible for many of the aircraft production plants erected at this same time, Severud was yet another internationally prominent engineer who had immigrated to New York in 1923, establishing a consulting firm with several German members. The augmented hangar of 1941, entitled an "Operations-Transport Squadron and Flight Test Hangar," was a redesign of Kahn's hangar executed by a New York collaboration of architects and engineers that included Severud (the Air Depot Architect Engineers).[26] By 1944, the hangar was in further transition—by Severud alone, as the "Hangar (Expandable) for V.H.B. Aircraft." The V.H.B. hangar accommodated the "very heavy bomber," the B-36 (briefly known after World War II as the V.V.H.B., or "very, very heavy bomber," to distinguish the plane from the B-29). Only a few of these prototype B-36 hangars, which were shallow structures similar to nose docks, went up. Verified locations include Eglin Field in Florida, as well as Fairfield-Suisun Army Air Base (Travis Air Force Base) and San Bernardino Army Air Field (at the former Norton) in California (Plate 5).[27] The Air Force did not select an ultimate hangar for the B-36 until 1951. That structure, a double-cantilever steel hangar, derived some of its key features from Severud's work.[28]

The B-36 was centrally important to Army Air Forces doctrine and to anticipated missions of the airborne American military as World War II ended and the Cold War simultaneously began. While the B-50 would improve the speed and combat radius for strategic air warfare, the Army Air Forces and the follow-on Air Force advocated a primary need for bombers with intercontinental range and jet capabilities. Before its entry into the war, the Army had realized that Europe might be lost as a combat staging ground, and that the ideal solution was the development of a bomber that could make a round trip to Europe from airfields in the continental United States. In April 1941, the Army Air Forces had contracted with Vultee Aircraft, the predecessor of Convair, for the B-36 Peacemaker. Contract stipulations included the ability to deliver a 10,000-pound bomb load to European targets from American bases; a 10,000-mile unrefueled flying range; and, a top speed of 240 to 300 miles per hour. For a variety of reasons, design and development of the B-36 was slow and progress toward the

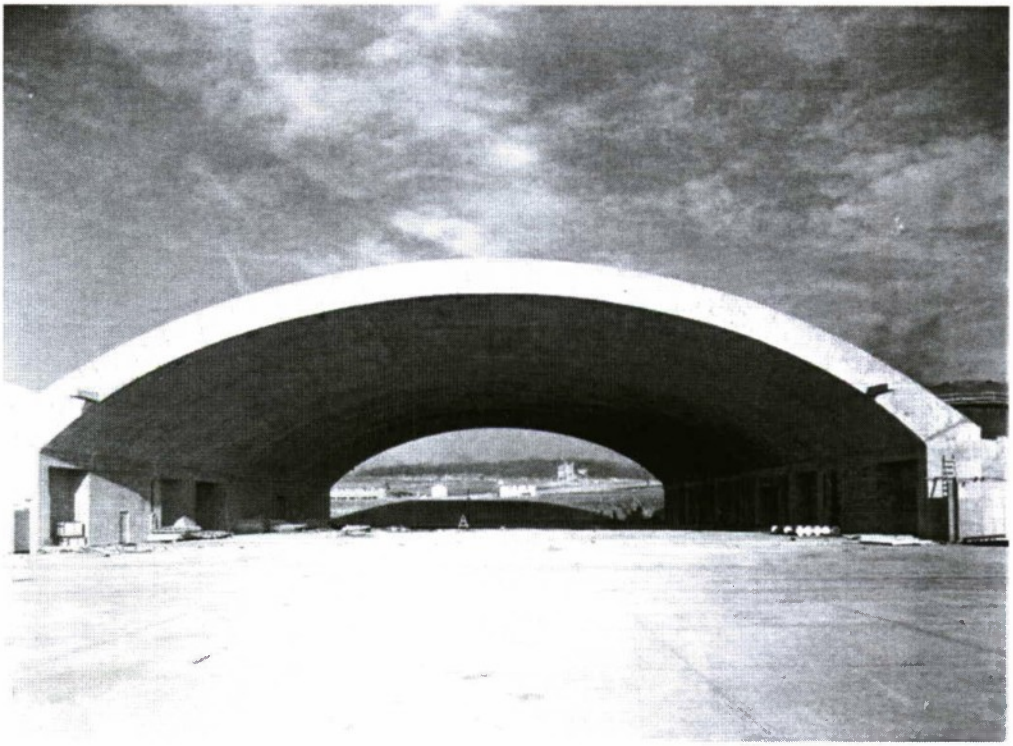

Plate 3: Anton Tedesko (Roberts & Schaefer). Modification Hangar (Building 20004), Wright Field. Single bay under construction, 20 January 1944. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

Plate 4: Anton Tedesko (Roberts & Schaefer). Signal Corps Hangar (Building 20006), Wright Field. Under construction, 11 January 1943. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

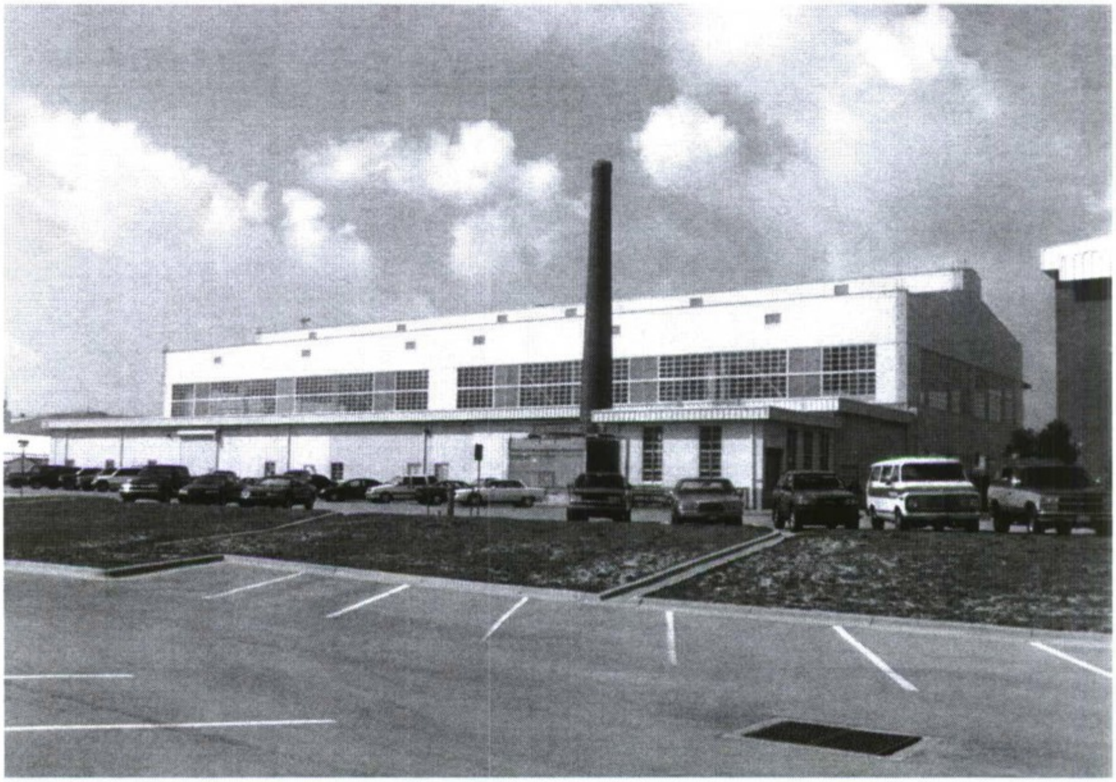

Plate 5: Fred N. Severud. Hangar (Expandable) for V.H.B. Aircraft (B-36 Maintenance Dock, Building 110), Eglin Field, 1945. Photograph of February 2000. C. Dolan for EDAW, Inc.

bomber really only picked up in 1944. Immediately following the end of the war, Curtis LeMay—who had directed B-29 incendiary raids over Japan and who would become the commander of SAC as of the late 1940s—argued strongly that the B-36 was essential for nuclear retaliatory capability against the Soviet Union. The B-36, first as a propeller-engined bomber and then as a jet-augmented aircraft, became the plane to carry the bomb: the B-36 first flew in August 1946, with major design improvements in 1949. In a strategic doctrine of long reach, flexibility and deterrence, the B-36 supported much extended airborne times, and when placed at overseas forward staging air bases made both an actual military statement and a cinematic one clearly understood by the American people. Ideal achievements of range, speed, weapons-carrying capabilities, and refueling evolved between the arrival of the first combat operational B-36 in 1948 and its final version, the B-36J, as of the middle 1950s. The B-36 was the bomber outfitted for advanced atomic and thermonuclear tests in the Marshall Islands and at the Nevada Proving Ground. The bomber was one of the first major symbols of the Cold War.

In addition to their efforts toward thin-shell concrete and steel cantilever maintenance hangars for the B-36, architectural-engineering firms designed three other structures for early testing of the bomber (Plate 6). Like Severud's V.H.B. hangars for Eglin, Norton, and Travis, these structures each dated to 1944. A Static Structural Test Laboratory at Wright Field, designed by the Chicago firm of Hazelet & Erdal in 1943 and under construction in 1944, featured an interior space capable of housing most of the B-36 fuselage and its 230-foot wing span. Although the plane could not be rolled into the structure nose-to-tail, nor could the whole of the aircraft be in test at any time, the laboratory was tall enough to allow rotation of the partial B-36 into a vertical position[29] (Plate 7) (see Volume II, Chapter 14). A second 1944 hangar at Eglin also accommodated testing for the B-36. A structure designed

Plate 6: B-36 at Wright-Patterson Air Force Base, undated. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

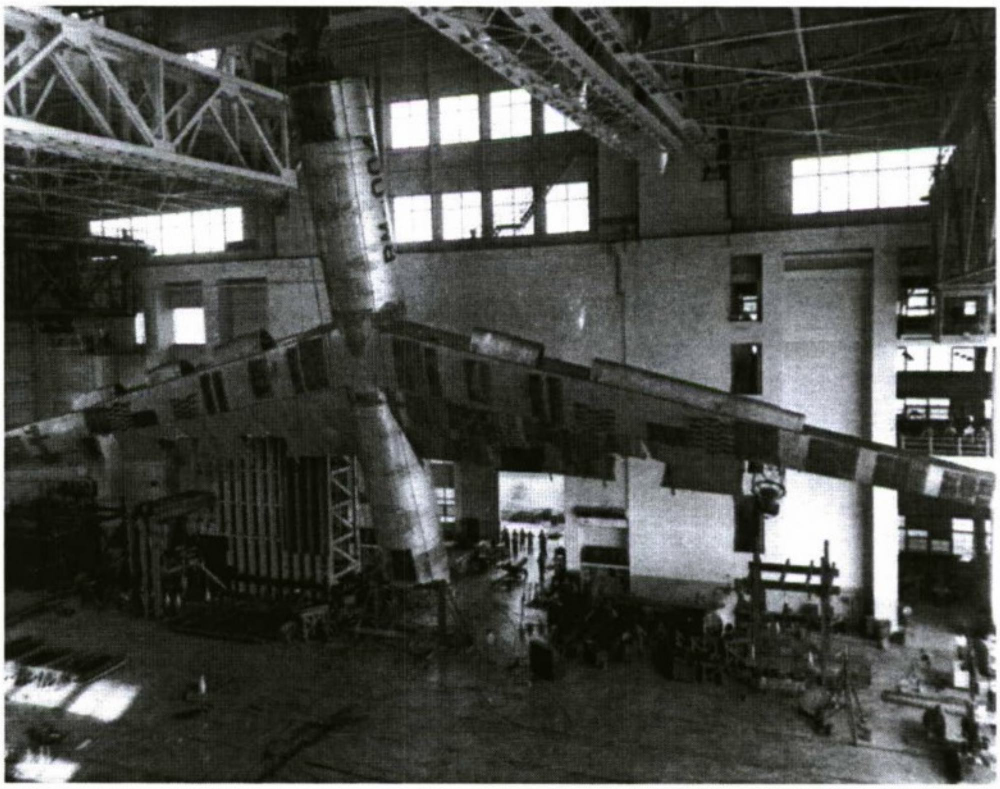

Plate 7: B-36 Fuselage in the Static Structural Test Laboratory (Building 20065), Wright-Patterson Air Force Base, undated. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

by Robert & Company of Atlanta, the climatic hangar was Wright Field's answer to unreliable aircraft and weapons testing under extreme cold-weather conditions. Arctic experts at Wright Field decided on placing the hangar at the Air Proving Ground in Florida after dismal results in outdoor testing at Ladd Field in Alaska. The winter of 1942-1943 had been so severe that operations at every field between Great Falls, Montana, and Ladd had been grounded due to the cold, making aircraft delivery to Russia impossible. Winter conditions that year grounded the Luftwaffe as well. (Choice of the balmy Florida site, while counter-intuitive, was tied to the location of the Air Proving Ground and major armament testing there.) Eglin's climatic hangar was originally intended to test whole aircraft only up to the size of the B-29, and although the structure did allow the entire B-36 into its interior for enclosed, cold-weather tests, adaptations making this possible were last-minute[30] (see Volume II, Chapter 4). The third structure designed for B-36 testing was the Experimental Building erected at a Convair bomber assembly plant in Fort Worth, Texas (Air Force Plant No. 4). The plant, designed by the Austin Company of Cleveland in 1940, handled the B-24, C-87, and B-32 production process, adding the B-36 mission on paper in late 1942. The Experimental Building of 1944, a steel trussed structure of 300 by 300 feet, accommodated the whole of the bomber but was otherwise a conservative structure (see Volume II, Chapter 15). Convair rolled out the XB (experimental bomber) -36 prototype on 8 September 1945, a little over three weeks after Japan surrendered unconditionally.[31]

Other major civil engineering achievements for the anticipated B-36—not surprisingly also associated with the emerging Air Materiel Command—included new runways as of 1944-1945. Although beginning in 1941 with subsurface and paving experiments for the XB-19, runway innovation for the B-36 required an exponential leap. The bomber's 300,000-pound weight, initially concentrated on two wheels, led to futuristic predictions for "catapult and rocket launchers, reverse propellers or aerial tugs for landing, caterpillar treads in place of wheels, and paved tracks instead of runways." At Wright Field engineers had carried such ideas forward in 1942 with an inclined runway constructed at a 10-percent grade to test the accelerated take-off and foreshortened landing of the B-18 (Plate 8). Wright Field modeled its experiment after a German effort in occupied France.[32] The weight of the B-36 gave further rise to growing concerns about the fit between very heavy bombers and then-existing infrastructure. In a Washington, D.C., meeting on 6 June 1944, as the invasion of Normandy unfolded, engineers informed Commanding General of the Army Air Forces Henry H. (Hap) Arnold that while Convair promised a flight test of the XB-36 soon, in fact there was no available test site. Engineers had concluded that the XB-36 would break through any pavement in the country. Longer, wider, and much more substantial runways became an immediate priority, particularly at airfields where the first B-36s would be tested (and subsequently, at airfields where the bomber would become operational). Immediate experiments with differing thicknesses and with the composition of subgrades, including what engineers termed second-story overlays, occurred on a large oval test track at Lockbourne Field in Columbus, as well as other tests at locations in California, Florida, and Alabama. Predicted costs for retrofitting any one airfield ran to $7,000,000. Engineers described the load on each wheel of the B-36 as similar to the "weight of a large locomotive carried on one tire, or to a column of concrete 3 feet 8 inches in diameter and 100 feet tall."[33]

For Air Technical Service Command, the priorities were a runway at its Convair production plant in Fort Worth and at the Air Proving Ground at Eglin, as well as augmented hard stands for particular facilities. During 1944, engineers at the Static Structural Test Laboratory at Wright Field, where the fuselage and wing span of the B-36 would also soon undergo testing, employed a 30-inch thick foundation, set on bedrock, with its 150-ton crane embedded in rock down to 37 feet and further sealed in concrete.[34] Convair requested a 10,000-foot runway in Fort Worth as of October 1944. Army authorization there was for a 8,200-foot runway, with massive substructure.[35] Capture of the Marianas during the summer of 1944 had shifted emphasis in Army engineering circles to building B-29 bases for the Pacific theater, simultaneously allowing a slowing of the pace in B-36 runway

Plate 8: Ten-Percent Inclined Runway, Wright Field, 1942. B-50 on the runway in 1953, with Building 20065 in background. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

development stateside.[36] Nonetheless, the War Department authorized a 10,000-foot B-36 runway at Eglin as of June 1945. First runways for the B-36 needed up to 40 inches of substructure to support an asphaltic surfacing, or high-quality concrete infrastructure of about 20 inches. Workers completed construction of Eglin's runway and its ancillary apron—allowing access to the climatic hangar—by September, just after the end of the war.[37] During 1947-1954, key B-36 runways would go in place at Wright-Patterson, Edwards, Kelly, and Kirtland Air Force Bases (Ohio, California, Texas and New Mexico), each by then a part of the new Cold War air materiel mission, and at Rapid City and Limestone (Ellsworth and Loring) Air Force Bases for SAC (in South Dakota and Maine respectively). At some installations in the late 1940s and early 1950s, including at least Kelly, Kirtland, McClellan, and Tinker, engineers temporarily beefed up existing runways for the bomber. Earliest plans for a B-36 runway at Wright-Patterson date to March 1947, with intentions for a 15,000-foot concrete runway able to handle a 300,000-pound loading, to be completed in segments. The "VHB" runway did not go in until 1950, at Patterson Field rather than at Wright Field—separated from the Static Structural Test Laboratory of 1944.[38] The concrete runways at Kirtland (15,000 feet) and Edwards (16,800 feet) were the longest in the world when completed during the middle 1950s, with that at Edwards able to support aircraft weighing up to 500,000 pounds.[39]

Command Organization: Installations in the Cold War Era

As World War II Concluded

With the formal end of World War II in September 1945, developments accelerated toward an expansion of the command mission for air materiel, even as the Army mothballed installations across the United States. Immediate administrative reorganization led the Army Air Forces to establish the

Army Air Forces Air Technical Base, Dayton. The organization chiefly oversaw housekeeping and planning functions for the area's cluster of installations, including Wright and Patterson Fields; Clinton County Army Air Field in Wilmington; and, Dayton Army Air Field in Vandalia. Regulations of 1 July 1945 had established a "T-Staff" system within Air Technical Service Command. Five sections comprised the T system: T-1, personnel; T-2, intelligence; T-3, engineering; T-4, supply; and, T-5, plans. The numeric designations parallel those of the Army today, with "2" denoting an intelligence mission; "3," operations; and "4," supply—with the contemporary alpha designation dependent on associated factors pertinent to general purpose. At the time of its institution, the "T" is assumed to have referenced "technical," as associated with the formal designation of the Dayton installation: Army Air Forces Air Technical Base.

The T-2 intelligence section of the Air Technical Service Command formed the nucleus of a future foreign analysis division. In 1945, T-2 took on the collection and analysis of all types of information to be gleaned from Nazi Germany.

> One of the first occupation duties of the Air Force [*sic*] in conquered Germany was that of seeking out and impounding Luftwaffe documents, locating German technicians, scientists, and experimental specialists for interrogation, and securing the records of their work and experiments. It was intended that whatever the Germans had of worth, the AAF [Army Air Forces] should have, and whatever the Germans had hoped to develop, the AAF should know about. Strange devices were ferreted out, crated, and shipped to Wright Field for study at the ATSC [Air Technical Service Command].[40]

In March 1946, Air Technical Service Command transitioned to Air Materiel Command, with the T system of organization continuing. By May, Intelligence (T-2) summarized its activities to include a broader foreign analysis definition.

> At the moment we have collected some 3,500 tons of German equipment of which there are still 109 tons enroute; some 118 tons from Japan of which there are an additional 108 tons enroute, and more than 250 tons of documents. This equipment tonnage comprises 638 foreign aircraft engines (457 German, 160 Japanese, 11 British, 2 French, and 8 Italian); on hand at various AMC [Air Materiel Command] installations are 58 German aircraft (of which 9 are conventional models and the balance includes jets, rockets, and gliders) and 129 Japanese aircraft (of which 77 are on hand and 52 are enroute).[41]

Engineering (T-3) took over the mission of aeronautical R&D. Immediate emphasis turned to "airplanes of tomorrow"—especially jet propulsion and guided missiles.[42] Again, Germany's progress stimulated research. Many of the Army Air Forces' actions at the outset of the Cold War had direct ties to specific efforts already underway in Germany as of 1944, particularly the case for the unfolding research and development mission of an air materiel command. Wright Field had assigned two initial test sites for guided missiles, with all the futuristic associations that the devices implied. Both of these were in progress on the test ranges at Eglin as of February and autumn 1944. The Army used the first, a mock-up of a German V (Vergeltung or Vereinigung) -1 launch site, to prepare for Operation Crossbow. The launch site functioned as a target cluster, featuring an inclined launch track for the V-1. Crossbow was a British military effort, initiated by Winston Churchill in

December 1943. The operation planned to destroy the V-1 launch sites in France and had an ultimate goal of eliminating all German long-range weapons aimed at British targets. By July 1944, a technical advisor to the European Theater of Operations had salvaged actual working parts of the V-1 and shipped these to Wright Field. Replication of the V-1's pulsed jet engine, supported through collaboration between engineers at the installation and wartime contractors, led to the JB (jet bomb) -2, the American version of the V-1. The Army Air Forces erected a JB-2 launch facility, with four initial launch ramps, on a test site directed overwater from Eglin's Santa Rosa Island (two of these were temporary ramps, a captured V-1 ramp and a short inclined trailer ramp). During 1945, JB-2 launches continued at the Air Proving Ground (see Volume II, Plate 47), with buildup for the 1st Experimental Guided Missiles Group as of February 1946. During 1946-1947, this earliest guided missiles mission for the Army Air Forces expanded to include another launch test site at the Wendover Bombing Range in Utah, with relocation from Wendover to Alamogordo Air Force Base (now Holloman) just before 1948. Holloman, too, would become an Air Materiel Command installation.[43]

T-3 consisted of four subsections, with each a grouping of laboratories: service engineering; aircraft and physical requirements; propulsion and accessories; and, electronic. Associated functions within the engineering subsections were reasonably straightforward, with the exceptions of aeromedical research (within aircraft and physical requirements); and, armament and photographic research (within propulsion and accessories). The Army subsumed all communications, navigation, and radar experimentation within "electronic." The newly created T-3 featured 14 total laboratories, including nine aeronautical and five electronic. From this juncture in 1945 forward, the R&D half of an air materiel command truly begins to expand. With 13 of its 14 laboratories at Wright Field, Air Technical Service Command had added the Watson Laboratories in Eatontown (Red Bank), New Jersey, as the fifth laboratory within the electronic subsection of T-3. Air Technical Service Command assigned the Watson Laboratories the development of ground electronic equipment, including communication devices and radar.[44] The Army's Signal Corps had established the Watson Laboratories as one of three radio, radar, and electronics laboratories near Fort Monmouth during 1940-1941: the Camp Coles Signal Laboratory, the Eatontown Signal Laboratory, and the Evans Signal Laboratory. In early 1945, the Army renamed the Eatontown facility the Watson Laboratories, after Lieutenant Colonel Paul Watson, team leader for the development of the Signal Corps' first long-distance radar. The Watson Laboratories sustained two field operations at the close of World War II: the Florida Field Station in Clermont and the Cambridge Field Station in Boston.[45] Under Air Technical Service Command by late 1945, management of the Watson Laboratories paralleled the structuring at Wright Field to which the laboratory then reported.[46]

T-3 also established full-scale outlying installations and liaison offices at this time, turning to both government agencies outside the Army Air Forces and ones that were oriented directly toward pure research.[47] The end of the war with Germany and Japan had created an immediate dilemma for future-directed R&D within the American military. While the impetus for research remained strong, wartime mechanisms disappeared and the vacuum posed urgent challenges. The federal government dissolved the Office of Scientific Research and Development (OSRD), as well as the National Defense Research Committee (NDRC) immediately after the war. Those organizations, created by Executive Order in 1940 and 1941, had mobilized "scientific manpower and facilities," and had made possible a tight coordination of "research and development on weapons, devices of warfare, and problems of Military Medicine." The OSRD had provided the Army Air Forces with basic electronics research through two essential academic laboratories in Boston: the Radiation Laboratory at the Massachusetts Institute of Technology (MIT) and the Radio Research Laboratory at Harvard.[48] The NDRC had orchestrated complex testing of precise incendiary bombs using napalm; large bombs and initial high-velocity aircraft rockets (HVARs); and proto-hardened, reinforced concrete construction—experimentation strongly overlapping efforts at Wright Field and generating specific

test sites at the Air Proving Ground in Florida.[49] The federal government transferred many of NDRC's active research projects to the Research Board for National Security, scheduling others to be dropped unless adopted by another agency. T-3 considered a number of NDRC's ongoing R&D efforts as vital to the Army Air Forces and, after the dissolution of the NDRC, directly took on the task of reviewing and evaluating those projects. Selected former-NDRC projects became those of Air Technical Service Command, and after March 1946, those of Air Materiel Command. The NDRC had relied heavily on contractors (such as Standard Oil for its napalm and incendiaries research). For active projects transferring from NDRC to Air Technical Service Command, the command at Wright Field took over the contracts themselves—providing funding and initiating a major new role in industry- and academic-contracted science.[50]

Recreating a mechanism that included scientists dedicated to pure research, while simultaneously integrating a science team into a military applied-engineering setting, became a goal for aeronautical R&D that accrued to Air Technical Service Command.[51] Such Army Air Forces R&D installations were already in place at Ladd Field (Fairbanks) for cold-weather testing and at Eglin's Air Proving Ground and would grow into a web of complementary facilities. Before the close of 1945, the headquarters engineering mission at Wright Field initiated ambitious test sites at Muroc Field (the future Edwards Air Force Base); Wendover Field (for expansion of the guided missiles mission then at Eglin); Boca Raton, Florida; and, Dover, Delaware. Muroc offered its dry lake bed, a natural desert feature that supported a five-to-six-mile runway in any direction for flight testing of experimental aircraft unobserved by the public. Wendover was similarly isolated and surrounded by many miles of uninhabited acreage. Boca Raton provided a field station for an electronic subsection of T-3 responsible for testing developmental radar equipment. Dover Field augmented the Armament Laboratory at Wright Field, with a test station for rockets and their installation on aircraft. From this date forward, Eglin expanded its ties to the Army Air Forces Technical Base in Dayton, closely supporting the Armament Laboratory at Wright Field and preparing to take over the cold-weather test mission as well. As of late 1945, direct liaisons between Wright Field and NACA strengthened, particularly between NACA's Aeronautical Laboratory at Langley Field in Virginia and its Ames Aeronautical Laboratory at Moffett Field in California. Related liaisons included one with the Cleveland Aircraft Engine Research Laboratory. Important university affiliations continued to be MIT and Harvard; the California Institute of Technology in Pasadena; and, the Applied Physics Laboratory at Johns Hopkins University in Baltimore. Specialized Army installations also sustained their earlier links to Wright Field, including the Chemical Warfare Service proving grounds at Aberdeen in Maryland and Dugway in Utah, and the Ice Research Base in Minneapolis.[52]

The changes accruing to a nascent air materiel command, critically supported by scientists, engineers, and academicians outside the military and its civil service, stimulated first attempts to bring such personnel inside the Army system—with relocation to Army installations. The seasoned senior scientists and engineers, however, rarely wanted to leave their universities or corporate lives. Salaries under civil service were much lower than comparable academic or business positions for these men. Most also possessed a keen desire to stay in the educational and social circles offered by venues such as Boston, rather than work in isolation. Further complicating matters, wartime graduates of American universities in science and engineering were notably few, with returning soldiers most often recruited for industry. General Arnold had glimpsed some of these concerns during 1944, almost as soon as an Allied victory became likely. Arnold accurately realized that the academic and industrial underpinnings of the Army's aeronautical R&D would likely disperse, and that the Army Air Forces required a formal plan. To address such a scenario, General Arnold turned to Dr. Theodore von Karman, a distinguished, leading aeronautical scholar at the California Institute of Technology. Arnold and von Karman had known each other since the middle 1930s, when Arnold commanded nearby March Field. In 1938, Arnold had called upon von Karman while he was chief of the Army Air Corps. With the entrance of the United States into World War II, von Karman formally

became a scientific advisor to Arnold and to the commanding general of the research laboratories at Wright Field. In September 1944, General Arnold asked von Karman to study the future of aeronautical science to help the Army Air Forces shape its endeavors toward a sustained and successful air domination to the year 2000. General Arnold wanted a blueprint to address such emerging technologies as "jet propulsion, atomic energy, and electronics."[53]

Dr. von Karman agreed to assemble scientists at the Pentagon and conduct General Arnold's study—an effort that General Arnold insisted be supported through travel to northern Europe, Russia, and Japan to assess the state of aeronautical science abroad. Von Karman was Hungarian by birth; German, by education and training. His doctorate from Göttingen University in 1908 focused on aerodynamic drag, with applications to aircraft, ship, and bridge design. Dr. von Karman taught first at the Polytechnic Institute at Aachen, working for the Austrian Air Service as an aircraft designer during World War I and returning to the university environment as Director of the Aachen Aeronautics Institute during the 1920s. Shortly after the founding of the Guggenheim Aeronautical Laboratory (GALCIT) at the California Institute of Technology, professor von Karman lectured there in 1926, subsequently invited to become the director of GALCIT. In 1929, Dr. von Karman accepted the California offer—driven partially by the incipient rise of Nazism on the Aachen campus. During the 1930s, the California Institute of Technology's aeronautical laboratory rose to rival the Aachen Aeronautics Institute. With the aircraft industries also centered in Southern California, an intertwining of academia and industry was inevitable, and in 1942 Dr. von Karman and his students organized the Aerojet Engineering Corporation to fabricate liquid- and solid-fueled small rocket engines. By 1944, Dr. von Karman had garnered an Army contract to develop tactical ballistic missiles for GALCIT, thereafter known as the Jet Propulsion Laboratory and soon erecting test stands at Muroc Field in the California desert to the east. Dr. von Karman immediately went to Eglin in October 1944 to study aeronautical test sites there.[54]

By the close of 1944, the Army Air Forces named the von Karman group of scientists at the Pentagon its Scientific Advisory Group (SAG). Seven other prominent men joined Dr. von Karman, primarily from the California Institute of Technology, MIT, and Harvard. Advising on a more irregular basis were another 21 men, including additional representatives of these universities, as well as men from Princeton, Brown, Johns Hopkins, Cornell, and the University of Illinois; from selected military laboratories and think tanks; and, from the aviation and munitions industries. In late April 1945, a reconnaissance team headed by Dr. von Karman left for London on a several-month trip that would take them to meetings with captured German scientists, to sites of former German laboratories, to caches of German documents, to laboratories in Moscow and Leningrad, and to Paris. Initially, the von Karman team traveled in Army uniform, joined by a separate team of 29 American industry engineers. The Army dubbed the team's efforts Operation Lusty. Dr. von Karman returned to the United States in July, submitting his draft study, *Where We Stand*, to General Arnold on 22 August 1945. By mid-December, the draft had become a 12-volume explication of the future entitled *Toward New Horizons* (see Volume I, Part III).[55]

Simultaneously with SAG's efforts of 1945, Engineering (T-3) at Wright Field moved forward to address concerns over the shortage of scientific personnel, and the imminent changes approaching with the end of the war. Early in the year, each laboratory began to plan for its future needs, post armistice. In May, War Department Special Staff directed Air Technical Service Command at Wright Field to update "Project B-7," a five-year post-war research and development program intended to make projections through fiscal year (FY) 1950. T-3 staff completed the report in June, paralleling the work of Dr. von Karman, but focused tightly on T-3 "facilities, the scope of the postwar research and development program, utilization of facilities, personnel requirements to accomplish the work, and the estimated over-all costs of operating the organizational components." The War Department used the report written at Wright Field to present budgetary arguments before Congressional

committees, turning to the business of operating an air materiel command post-World War II even as SAG approached the Army Air Forces-and-aeronautical science from a much loftier point of view.[56] That same month, advisors to Brigadier General F.O. Carroll, chief of T-3, realized that internal Wright Field recommendations for future R&D facilities really required "a new military installation for research and development testing exclusively...in some region where large scale power, water, and land resources would be available."[57]

By July 1945, the inspection efforts of Dr. von Karman had highlighted the sheer magnitude of the German aeronautical progress during the war, keenly noting the elaborate physical facilities that underscored that progress. As a result, the Air Staff directed that an engineering study be undertaken in support of the idea of a wholly new Army Air Forces R&D installation. The Army Air Forces immediately chose to revise its FY 1946 R&D budget in August, and in September T-3 at Wright Field redid its projections of the previous June, adding $75,000,000 per year to its estimates for sustained aeronautical excellence. In October, T-3 established a committee to prepare the engineering study requested by the Air Staff. Again paralleling the ongoing efforts of SAG, the T-3 committee

> made an exhaustive study of existing research and development facilities, both foreign and domestic, and projected plans for new weapons. From these studies, facility requirements were determined and a master plan was prepared for the proposed Air Engineering Development Center.

Of note, T-3 issued its report, *Proposed Air Engineering Development Center*, on 10 December 1945, forwarding it to the Air Staff four days later—exactly one day before the formal deadline and submittal of Dr. von Karman's *Toward New Horizons*.[58]

Wright Field's proposed Air Engineering Development Center of late 1945 would become the Arnold Engineering Development Center of the early 1950s near Nashville, Tennessee, sharing the same acronym (AEDC). The AEDC was to support both government agency and industry R&D toward military aeronautical engineering.

> The facilities were to include wind tunnels for testing aircraft, missiles, and complete propulsion systems. The facilities were to be capable of testing aircraft at subsonic to supersonic velocities. Temperature and density conditions corresponding to the standards for altitudes of 80,000 feet above sea level were to be simulated. Other facilities were to accommodate the components of specific propulsion systems such as turbines, compressors, ducts, and nozzles. The proposed plans called for rocket test stands suitable for testing engines with tremendous thrust. Additional facilities were planned for testing structures, materials, instruments, electronics equipment, and fuels. The estimated initial expenditure for the proposed Air Engineering Development Center was approximately $300,000,000.[59]

Site surveys for the AEDC, before the command made its final decision based on the availability of hydro-electric power through the Tennessee Valley Authority (TVA), included long looks at the Moses Lake area of eastern Washington (what would become Larsen Air Force Base) and at the Las Vegas-Lake Mead area along the Colorado River (the future Nellis Air Force Base and its associated test ranges). By late 1948, the Research and Development Directorate, Headquarters Air Force, in Washington, D.C., considered the Lake Mead site untenable due to foreseen battles over

hydro-electric power usage between the Air Force and the City of Los Angeles (through Southern California Edison).[60]

Planners of an AEDC envisioned the installation as an campus-like enterprise, closely affiliated with industry. Air Technical Service Command also proposed an AAF Institute of Technology, using as its nucleus the Air Corps (later AAF) Engineering School founded at Wright Field in 1927 (and ultimately derived from the Air Service School of Application established at McCook Field in 1919).[61] The Institute proposal dated to early August 1945, partially driven by the von Karman findings in Germany. The Army Air Forces officially established its Institute of Technology in mid-December 1945, with organizational efforts going forward during 1946. An Army Air Forces Institute of Technology Committee and another von Karman effort (the Markham Report) of March and April 1946 guided the setup of the school's aeronautical engineering curriculum. The Institute of Technology, successor to the Engineering School at Wright Field, was "to train qualified officers in general and specialized subjects appropriate to the research, development, procurement, supply, and maintenance of equipment used by the AAF."[62] By the end of 1947, enrollment at the Institute of Technology reached about 270 students.[63] The idea of a technological university community resurfaced more than once within the command. A university was present in studies for the AEDC itself during the late 1940s and again in efforts of the middle 1950s toward a development center for the testing of intercontinental ballistic missiles (ICBMs). The Air Force board assigned to the problem set in 1954-1956 (known as the Yates Committee) proposed Holloman Air Force Base in southern New Mexico for the missile test center, a siting decision that would ultimately shift to Vandenberg Air Force Base in Southern California. German advisors at Holloman, a group of men from Project Paperclip first stationed at Fort Bliss in El Paso, advocated inclusion of an Institute of Space [Flight] Technology to offset the isolated conditions of the location. Their solution to the intellectual drawbacks posed by a remote testing site was similar to that of the Germans during World War II at Peenemünde.[64] By 1966, a similar specialized academic facility formally associated with the Air Force, the University of Tennessee Space Institute, would exist adjacent to the AEDC at Arnold Air Force Station (subsequently, Arnold Air Force Base) (Plate 9).

Severe challenges in attracting American scientists to the laboratory locations of Air Technical Service Command had emerged immediately after Victory in Europe (VE) Day in June 1945. Pending closure of the Radiation Laboratory at MIT, scientists were unwilling to transfer to laboratories at Wright Field or to the Watson site in New Jersey. As of mid-August, military officers under Air Technical Service Command actively undertook recruitment of civilian scientists at MIT for an expansion of the existing Cambridge Field Station. The field station was directly affiliated with the Watson Laboratories, but more amenably located in Boston. The expanded Cambridge operation consisted of 19 persons—out of an interviewed 852—on temporary duty for the Watson Laboratories by early September 1945. Projected personnel strength for the Watson Cambridge installation was 26 officers and 500 civilians. The post-war Cambridge Field Station was "to assume and execute the functions of research and development of radio and radar equipment peculiar to the AAF, transferred to the ATSC from the National Defense Research Committee."[65] As of early November 1945, Brigadier General George C. McDonald of Headquarters United States Air Forces in Europe, further wrote Major General Hugh Knerr of Air Technical Service Command at Wright Field, to note that the Royal Air Force (RAF) in Britain had suggested an aeronautical research center in Bedford, Massachusetts, in which

> they [the RAF] propose the installation of all the vital pieces of equipment of the Hermann Goering [Göring] Institute, Volkenrode, Brunswick, and the Kaiser Wilhelm Institute I, at Göttingen. They have refused to release any of the German scientists in their custody whom we have previously selected, because they intend to have them continue work at this new center.[66]

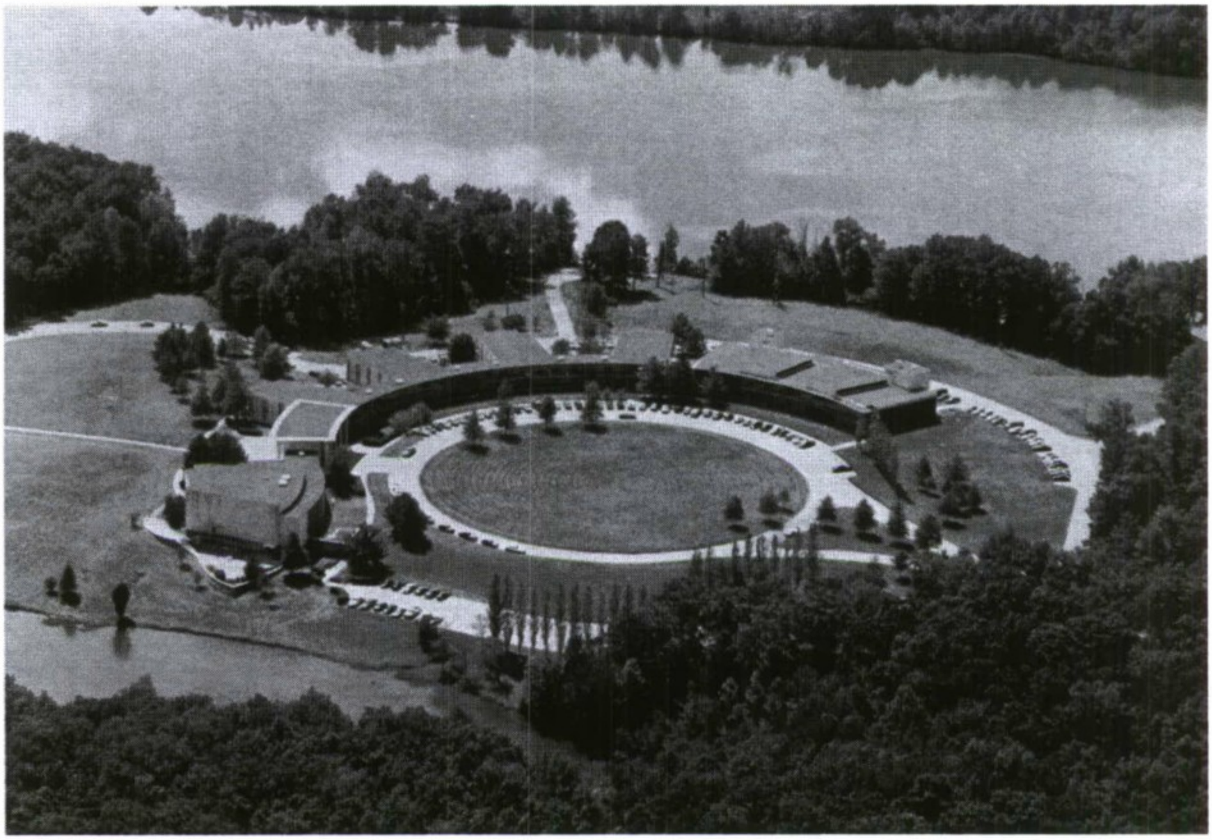

Plate 9: University of Tennessee Space Institute, near Arnold Engineering Development Center, 1966. Aerial view of 1985. Courtesy of the Office of Public Affairs, Arnold Engineering Development Center.

The Cambridge Field Station would grow into an electronic and air defense research facility at Hanscom Air Force Base, in Bedford, as the Cold War unfolded—foreshadowed at that location by the RAF in 1945. The RAF idea was grand in scope, and, in fact, would be spread across Air Research and Development Command (ARDC) during the early 1950s. The Göring Institute (the Luftfahrtforschungsanstalt Hermann Göring [LFA]) was the premier aeronautical center in Nazi Germany. The Kaiser Wilhelm Institute was intimately attached to a second aeronautical research center in the university town of Göttingen (the Aerodynamische Versuchsanstalt Göttingen [AVA]), with its Berlin division responsible for research in nuclear physics toward development of an atomic bomb.[67]

The Watson field installation, first located in a building on Albany Street in Cambridge, also took over several outlying World War II test facilities of MIT, establishing a pattern of ancillary sites that would become characteristic of both the command's R&D mission in Boston and, soon, its future one in Rome, New York. First ancillary test sites associated with the Watson Cambridge Field Station were the Ipswich antenna test facility and a nucleus of six woodframe temporary buildings at the Bedford Army Air Field (later Hanscom Air Force Base). From this modest beginning, the Boston arm of R&D for Wright Field would conduct test series related to communications-electronics at far-removed locations. First major off-site efforts were for an airport traffic control system radar at the All Weather Flying Center of Air Technical Service Command at the Clinton County Army Air Field in Ohio, and measurement experiments for "sky brightness" during firings of captured German V-2

rockets on White Sands Proving Ground in southern New Mexico near Alamogordo Army Air Field (later Holloman).[68]

The T system of Air Technical Service Command at the end of World War II served not only as the managerial umbrella for the Army Air Forces aeronautical research and development efforts, but also as the supply and logistics side of the continuing air materiel mission. The geographical organization of the supply and maintenance installations changed only slightly during 1945. Supply (T-4) paralleled the hierarchical positioning of Intelligence (T-2) and Engineering (T-3) at Wright Field. The 12 Air Technical Service Command areas sustained one primary depot and subordinate specialized depots, with the Miami Air Technical Service Command jurisdiction remapped to include a small associated physical territory (Plate 10). Two key supply locations handled overseas materiel for the command, one located for Atlantic Overseas Air Technical Service Command at Newark, New Jersey, and a second, for Pacific Overseas Air Technical Service Command, at Oakland, California. The chief dilemma within T-4 as the war ended was aligning supply and maintenance: integrating and updating the system of available spare parts to the changing needs of modification, overhaul, and repair of aircraft. Previously, the organizationally distinct Materiel and Engineering Divisions of Air Service Command (Air Technical Service Command's predecessor) had not interacted efficiently at the headquarters level, working together best in field operations. Challenges persisted during 1945 within the T system due to the realization that many of the maintenance functions within an air materiel command had closer functional relationships to T-3 than they did to T-4, under which Air Technical Service Command subsumed both the supply and maintenance missions.[69]

When the war ended in Europe, issues for the depot side of the house were very much different than they were for R&D. While the workload did not lighten, the command shifted supply stocks to service the Pacific, with newly activated depots there. Simultaneously, disposal of surplus property became an issue with a view toward peacetime requirements. Decisions about what to hold in reserve and what to declare excess became even more pronounced with Victory in Japan (VJ) Day, 15 August 1945. Improved efficiency and accurate tracking of stock called for revised procedures in classifying, identifying, and cataloging property. As January 1945 opened, the command inventoried 654,992 distinct spare parts and equipment in its warehouses. By September, Air Technical Service Command recommended a world-wide stock control system. During the war the 12 depots established to support the command had also become specialized, with overhaul of specific aircraft allocated to distinct depots and with a relatively small number of different parts needed per physical location. Plans for conversion to peacetime recommended a downsizing from 12 to seven depots. The command favored elimination of Fairfield (at Wright Field), Middletown, Ogden, Rome, and Miami, and further envisioned that operations at Warner Robins, Mobile, San Bernardino, Sacramento, and Spokane would be greatly reduced. The proposed post-war Air Technical Service Command depot system looked toward a new hierarchy focused on just two depots, those in the center of the country at San Antonio and Oklahoma City, supported by small operations in the West and Southeast. San Antonio and Oklahoma City were to become the "major production-line overhaul depots." As of January 1946, the Fairfield Air Depot became the first depot of the World War II group to close.[70]

As of 1946, the unfolding air materiel command within the Army Air Forces (soon to be the Air Force) developed two distinct arms: one for research and development and one for maintenance and supply. In early March, Air Technical Service Command became Air Materiel Command. The Army's return to an earlier name, however, was not indicative of what lay ahead. While sometimes under the same command, and at other times in separate but parallel commands, the two missions of R&D and materiel supply-logistics each matured distinct from one another. The command quickly attached a web of installations to each. At the outset of the Cold War, the single largest addition to

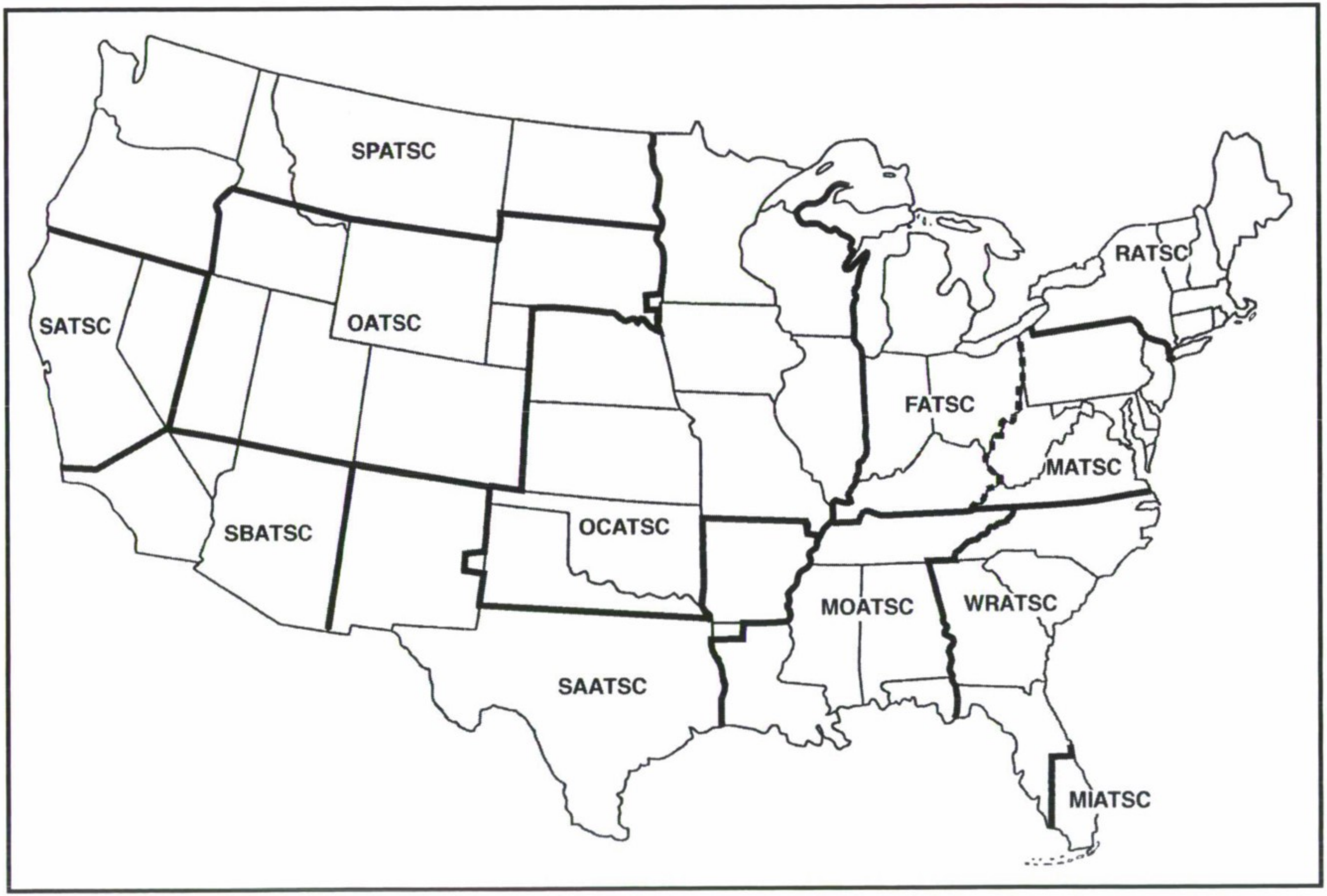

Plate 10: Air Technical Service Command Areas, 15 November 1945. In January 1946, the Fairfield Air Depot (FATSC) would be the first to close as the number of ATSC Areas contracted. Adapted from *History of the Air Technical Service Command 1945*, volume 2.

the overall mission of Air Materiel Command was that of operating the technical intelligence services of the Army Air Forces under T-2. Procuring and analyzing foreign intelligence remained paramount, with a storage depot sited at Freeman Field in Seymour, Indiana, until October 1946, thereafter followed by another specialized intelligence depot in Chicago.[71] The research and development mission moved toward inclusion of basic research, as well as toward research applicable directly to aeronautical needs, to more fully foster a future independence of an air arm of the Army. The supply-logistics mission, interpreted as procurement, turned toward a highly centralized structure that followed contemporary business and industry practices—a structure intended to keep peacetime activity limited, yet support a very rapid expansion in case of any military emergency.[72]

Research and Development Facilities

Under Air Materiel Command: 1946-1950

Continuing into 1946, the aeronautical R&D mission of Air Materiel Command stayed focused within Engineering (T-3) at Wright Field, organized as three divisions. The Engineering Division managed four subdivisions, which in turn managed laboratories and engineering shops. An aircrafts and physical requirements subdivision oversaw four laboratories: aircraft, aeromedical, materials, and personal equipment, while a propulsion and accessories subdivision oversaw five: armament, equipment, photographic, power plant, and propeller. An electronics subdivision also oversaw five laboratories: communication and navigation, special projects, systems engineering, radar, and engineering services. The fourth subdivision, service engineering, managed the shops, as well as the engineering standards and aircraft projects sections. With the inclusion of the Watson Laboratories off site in New Jersey and the Cambridge Field Station in the works in Boston, the electronics subdivision was the first to see major reorganization. Air Materiel Command's test site at Boca Raton Army Air Field, Florida, like the nascent Cambridge laboratory, came under the Watson installation as a field station during the year (inactivated in January 1947). Further expansion of the electronics mission included two experimental squadrons, the 4149th and 4150th Army Air Forces Base Units at Olmsted Air Field (the Harrisburg, Pennsylvania, depot location of the Middletown AMA) and Boca Raton respectively. Air Materiel Command disbanded the 4146th Army Air Forces Base Unit at Dover Army Air Field in September, concluding its rocket-propeller testing at that installation. The same month, the subdivision concept ceased, with the exception of the electronics subdivision. Air Materiel Command placed the remaining nine Engineering Division laboratories directly under its chief. Of the other two divisions of T-3, Flight Test and Maintenance, only Flight Test focused on research and development.[73]

Physical locations associated with R&D through Air Materiel Command during 1946 included 12 installations throughout the United States and one in territorial Alaska (Ladd Field). In the continental United States were Wright Field in Dayton; Lockbourne and Clinton County in Ohio; the Watson Laboratories in New Jersey; the Cambridge Laboratories in Boston (with its immediate test sites); Dover in Delaware; Olmsted in Pennsylvania; Boca Raton in southern Florida; the Air Proving Ground at Eglin in the Florida panhandle; Wendover Army Air Field in Utah (expanding the guided missiles mission from Eglin); Muroc Army Air Field in Southern California; and, Kirtland Army Air Field in New Mexico. Kirtland was "to provide flight services for the Manhattan District at Sandia and Los Alamos in atomic bomb testing."[74] During 1947, this situation largely continued, although regional administrative jurisdiction was increasingly muddied between the R&D installations within Air Materiel Command and its depots. The test efforts at Lockbourne, as well as those at Dover, ceased, but all others went forward. Generally, the AMA set up to handle the depot needs of the command also managed the R&D effort in proximity. The Middletown AMA oversaw the 4149th test unit and some of the needs of the Watson Laboratories; the Warner Robins AMA, Boca Raton; the San Antonio AMA, Kirtland; the Ogden AMA, Wendover; and, the San Bernardino AMA, Muroc.

Eglin sustained an independent command and jurisdictional status as Air Proving Ground Command, with cold-weather efforts at Clinton County and Ladd Fields more directly tied to Headquarters Air Materiel Command in Dayton. The most complex off-site R&D facilities were those for the electronics mission.[75] Following the transition from the Army Air Forces to an independent Air Force in the middle of 1947, Wright and Patterson Fields became Wright-Patterson Air Force Base at the outset of 1948.

During 1948, the R&D mission within the emergent Air Force took on entirely new dimensions and organizational structure, with the philosophy that the new era made it "logical that the field of research and development should assume a place of predominant importance in the stable, detached atmosphere of peace."[76] The peace described here was in actuality neither stable nor detached, and was instead already a "cold war" thought to be unfolding for no less than a 15-year period. In July 1947, George F. Kennan, an American diplomat to the Soviet Union and Russian culture expert, anonymously published a long, analytical article in *Foreign Affairs* entitled "The Sources of Soviet Conduct." Kennan's analysis predicted future Soviet behavior as a long standoff between that country and the United States. Foreign affairs experts immediately recognized Mr. "X" as diplomat Kennan, and in counterpoint journalist Walter Lippmann wrote *The Cold War: A Study in U.S. Foreign Policy*, a book published in New York and London before the year closed.[77] Within the Cold War, aeronautical progress was to be of cutting-edge necessity, and science definitive.

As 1948 opened, the R&D function stayed within the Engineering Division at Air Materiel Command, Wright-Patterson Air Force Base. The year, however, was one of organizational change. The Air Force had formally discontinued the T system at Air Materiel Command in October 1947 and moved toward a directorate scheme. The transition occupied most of 1948. The Engineering Division started the year with three categorical sections: laboratory, electronics, and control. What was by this date thought of as "laboratory" featured nine laboratories, while "electronics" also broke out as laboratories (three) and the off-site ancillaries tied to the Watson installation. The control function focused on the tasks of administration, plans, operations, and comptroller. Within its operations section were the subsections that contained the web of test and special-mission installations for the command. These subsections included aircraft projects (Muroc [Edwards] and Kirtland), aviation ordnance engineering (Eglin), climatic projects (Clinton County, Eglin, and Ladd), engineering liaison, and guided missiles (Eglin, Wendover, and Alamogordo [Holloman]). In February 1948, Air Materiel Command augmented the operations group with an applied research subsection. In July, the command also assigned Kirtland's atomic component of the aircrafts projects subsection its own subsection of special weapons.[78]

The applied research subsection of operations was the kernel of activity within the Engineering Division of Air Materiel Command that would witness the greatest shift. The command subsumed both applied and theoretical research within the new applied research subsection, with the latter element intended to attract and make possible the use of top scientists in a salary range generally above the limits of government employees (under Public Law 313 of August 1947). The caliber of the personnel led to a designation of "group" for the research subsection, with many efforts overseen by the hired scientists but conducted directly by universities and private industry. As a directorate system at Headquarters Air Force in Washington, D.C., moved forward with the establishment of the Directorate of Research and Development, the applied research subsection ("group") within the Engineering Division at Air Materiel Command at Wright-Patterson transferred to a created Office of the Director, Research and Development, within Air Materiel Command. As of February 1949, the original organizational R&D kernel at Wright-Patterson made a final move to the just-established Office of Air Research at the installation. Air Materiel Command assigned the Office of Air Research to the Office of the Director, Research and Development. The command simultaneously discontinued applied research within the operations subsection of the Engineering Division at Wright-

Patterson. The Office of the Director, Research and Development was alternately known as Air Materiel Command's Directorate of Research and Development, directly paralleling in name and structure that of the Directorate of Research and Development at Headquarters Air Force.[79]

During 1948-1949, physical locations for the research and development components of Air Materiel Command continued to expand to accommodate "electronics, supersonics, and guided missiles" (Plate 11). The command categorized the off-site installations as "exempted," not integral to the Engineering Division at Wright-Patterson but certainly supportive. "The installations were placed away from AMC headquarters in order to obtain climatic or terrestrial conditions, such as hot or cold weather, isolation for rocket testing, and air space for flying." To the previous Air Materiel Command R&D group, the command added a major mission at Griffiss Air Force Base in Rome, New York (already a depot location), and smaller research and development activities at Robins and Tinker Air Force Bases (both also depots). In addition, the 803rd Air Force Specialized Depot at Park Ridge, Illinois, functioned as an exempted Air Materiel Command R&D site into mid-August, when the command transferred the facility to Air Defense Command.

> The Muroc Air Force Base...was an ideal spot for testing experimental aircraft with greater safety than was possible at conventional airdromes in thickly populated areas. ...The wild open terrain of Holloman Air Force Base at Alamogordo, New Mexico, permitted the testing of pilotless aircraft, guided missiles, and allied equipment with comparative safety. The Cold Weather Test Detachment at Ladd Field, Alaska, was concerned with the winterization testing of certain items of equipment that had to stand up under cold weather conditions. The Kirtland Air Force Base in Albuquerque, New Mexico, provided field contact for the USAF [United States Air Force] with the Atomic Energy Commission and the Armed Forces special weapons project and furnished the necessary flight test facilities for these activities. ...Watson Laboratories at Red Bank, New Jersey, was primarily concerned with the development of prototype and service test models of ground electronic equipment peculiar to the USAF. The Cambridge Field Station at Cambridge, Massachusetts, was a scientific research installation that conducted basic and applied electronic and atmospheric research. The Griffiss Air Force Base at Rome, New York, became an exempted installation for AMC electronics activities on 1 April 1948. ...The 4150th Air Force Base Unit at Robins Field, Georgia, furnished shop facilities for installation and minor modifications of radar equipment and conducted the required flights for the testing of radar equipment as directed by the AMC. On 28 August 1948 this unit became the 3150th Electronics Squadron...[The 4150th Air Force Base Unit had moved from Boca Raton to Robins in late November 1947.] The Air Proving Ground Command at Eglin Field, Florida [briefly redesignated the Air Materiel Proving Ground]...tested all tactical materiel and equipment used or proposed for use by the USAF, under simulated combat conditions, to determine its operational suitability. ...On 1 September 1948 the 3075th Aircraft Ferry Squadron was established as an AMC exempted installation at the Tinker Air Force Base, Oklahoma City, to ferry aircraft to operational bases and move aircraft to and from plants and installations throughout the nation for the accomplishment of required modifications.[80]

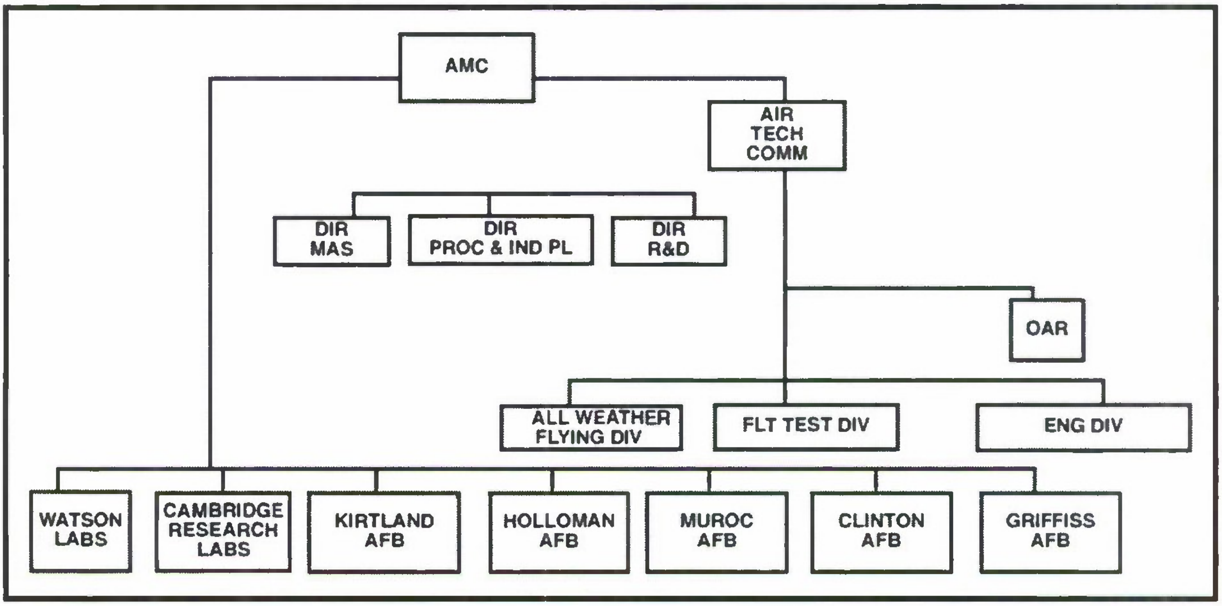

Plate 11: R&D within Air Materiel Command, September 1949. Adapted from *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

The all-weather flying R&D mission continued at Clinton County Field in Wilmington, Ohio, with experimentation focused on cloud physics and thunderstorm analysis, including seeding clouds with dry ice and chemical agents.[81] R&D exempted installations and affiliated major test locations for Air Materiel Command remained stable through the autumn of 1949. The most disruptive announcement within the command was the planned combination of the Watson Laboratories, the Cambridge Field Station, and the 4149th Electronics Experimental Flight Test Squadron (at Olmsted Air Force Base in Pennsylvania) at its research and development site on Griffiss Air Force Base in New York.[82]

Organizationally, the R&D mission of Air Materiel Command had been moving toward both coalescence and independence since Dr. von Karman's *Toward New Horizons* of 1945. The SAG charter had officially expired in early February 1946, but nearly immediately the Army Air Forces acted upon von Karman's advice to establish a permanent scientific advisory group. As of July 1946, the Scientific Advisory Board (SAB) came into existence, with several dozen leading American university and industry scientists paid to serve annual terms. The SAB languished as an institution during the transition from the Army Air Forces to the Air Force from mid-1947 to mid-1948. Nonetheless, by that date, the expanding web of test installations under Air Materiel Command, as well as its laboratories at Wright-Patterson, helped refurbish the planned role of the SAB. During the spring of 1949, Dr. von Karman was further able to influence the selection of Dean Louis N. Ridenour of the University of Illinois to chair a SAB committee to study the entire unfolding of research and development within the Air Force.[83]

> Research and Development was different to the point of uniqueness. The reason was its mission. Stated simply, that mission was to seek out and bring into the realm of the possible things that had never been done before in aeronautics. An inherent characteristic of such a mission was continuous adjustment to the unpredictable. Standard management measures used as organizational premises...were not generally applicable. Such measures were derived from experience

> accumulated through repetition of the same or similar operation. An experimental or development operation was largely a first-time, perhaps only a one-time, experience.[84]

The Ridenour Committee visited all of the Air Materiel Command research and development facilities during July and August—a practice for shaping the future that would continue steadfastly within the Air Force into the middle 1950s.[85] The committee submitted a report in late September 1949 that advocated reform of Air Force science, with the recommendation for a separate R&D command.[86] In mid-November, a parallel military committee chaired by Major General Orville A. Anderson (the Anderson Committee) at the Air University (Maxwell Air Force Base) submitted a separate study of the problem, with identical overall conclusions. The four-person Anderson Committee included Major General Donald L. Putt of Headquarters Air Force, Brigadier General Ralph P. Swofford, Jr., of Air Materiel Command at Wright-Patterson, and Colonel Keith K. Compton of the Air Proving Ground at Eglin. The committee noted that "Research and Development functions are submerged and diffused in a logistics [Air Materiel] command," and that the Air Force was "not establishing that partnership with science necessary to the exploitation of scientific frontiers." Major General Putt would become the first commander of ARDC.[87]

By October 1949, the Directorate of Research and Development had become the largest of three directorates within Headquarters Air Materiel Command at Wright-Patterson. (The other two Directorates were those of Procurement and Industrial Planning, and, Supply and Maintenance.) Air Materiel Command's Directorate of Research and Development then contained Engineering, Flight Test, and All-Weather Divisions, as well as the Office of Air Research (see Plate 11). During late December of the same year, in the initial restructuring of R&D as recommended by the Ridenour and Air University Committees, Air Materiel Command further consolidated the Directorate of Research and Development into three divisions, those of Research, Engineering, and Test.[88] The second six months of 1949 were highly fluid, as decisions continued to move toward an independent R&D command. While the process went forward, several of the research and development test installations under Air Materiel Command witnessed some significant changes. As early as July, Air Materiel Command had taken on the former Banana River Naval Air Station in Cocoa, Florida, with the intent to develop that installation into an armed forces proving ground for long-range guided missiles. Air Materiel Command's custody of the property continued until the end of September, when the Air Force transferred the site from the command to a new entity, the Joint Long Range Proving Ground Command. The next month, the Clinton County all-weather test site in Ohio closed and its mission moved to Wright-Patterson. During late November, the Air Force elevated the mission at Kirtland Air Force Base, previously under Air Materiel Command, to the command level. The Air Force subsequently situated Headquarters Special Weapons Command there. At Eglin, the umbrella organization became the Air Materiel Armament Test Center in mid-December, consolidating armament testing projects then underway at Eglin, the Army's Aberdeen Proving Ground in Maryland, Robins Air Force Base in Georgia, and Edwards [renamed from Muroc] Air Force Base in Southern California.[89]

Under Air Research and Development Command: 1951-1961

On 2 January 1950, the Air Force Vice Chief of Staff, General Muir S. Fairchild, convened most of the Air Staff deputy chiefs of staff to discuss the committee reports on R&D needs. The next day, General Fairchild formally outlined a transfer of Air Materiel Command's R&D responsibilities to a new, distinct command for the Air Force. Three weeks later on 23 January, the first iteration of the command—the Research and Development Command (RDC)—formally came into existence. Reallocation of the R&D assets of Air Materiel Command was to move forward between March and October, but as early as April the enterprise was proving too large for a simple transition. By

mid-October 1950, the Air Force Chief of Staff, General Hoyt S. Vandenberg, reiterated the direction desired and insisted that an Air Research and Development Command be in place as an "independent self-sufficient" command by mid-May 1951.[90] The name change from RDC had occurred formally on 16 September.[91] General Benjamin W. Chidlaw, commander of Air Materiel Command at Wright-Patterson, saw many problems ahead in separating what he called the "Siamese twins" of R&D and procurement. Working groups proceeded, with about 5,600 personnel involved in the division of Air Materiel Command assets.[92] To ease the change, the existing command supervised the R&D shift to ARDC. The new research command was to have its physical headquarters at Wright-Patterson, alongside the older Air Materiel Command which would continue to manage the procurement (supply-maintenance) mission. At what moment the R&D responsibilities of ARDC ended and those of the older Air Materiel Command recommenced, remained a sore and confusing issue. Perhaps the turning point had occurred in 1939, when the Air Corps had separated "experimental" and "production" engineering.[93] Yet research, development, testing, and evaluation for prototypes had continued to blend into the procurement and modification mission throughout the 1940s. As of April 1951, the fledgling ARDC no longer reported to Air Materiel Command, but directly to Headquarters Air Force.

A flurry of General Orders reassigned R&D installations and test facilities from Air Materiel Command to ARDC. The first of these, of 31 March 1951, issued from Headquarters Air Materiel Command, transferring Edwards, Griffiss, Holloman, and Wright-Patterson Air Force Bases; the Cambridge Laboratories (the latter redesignated from the Cambridge Field Station to the Cambridge Research Laboratories in July 1949); and the 2752nd Experimental Group at the Naval Auxiliary Air Station, El Centro, California.[94] Follow-on General Orders two weeks later (also from Headquarters Air Materiel Command) added the Watson Laboratories; the Climatic Projects Laboratory at Mount Washington, New Hampshire; and, the Upper Air Research Station at Sacramento Peak, New Mexico—sited southeast of Holloman Air Force Base in the Sacramento Mountains.[95] Air Force Regulations 23-2 and 23-8, issued the next month, then stipulated "cradle to the grave engineering" as the primary mission of ARDC.[96]

During 1950, while the transition from Air Materiel Command to ARDC was in progress, the Air Force R&D physical locations sustained those of 1949, with some expansion of the climatic and upper atmosphere missions, and with the formal transfer of an Air Engineering Development Division (AEDD) at Wright-Patterson to Tullahoma, Tennessee. Winter testing moved forward at Ladd Field in Alaska, supplementing controlled tests in the climatic hangar at Eglin. The climatic hangar supported tests down to –65 degrees Fahrenheit. Additional cold weather studies, focused on thermal anti-icing systems for aircraft and managed out of Wright-Patterson, were underway at Willow Run, Michigan (west of Detroit), and at Mount Washington, New Hampshire (north of the Cambridge Research Laboratories). At the other extreme, the command initiated hot weather studies at its Actinic Test Site in Las Cruces, New Mexico, to the southwest of Holloman. There scientists kept materials exposed to the desert sun to analyze deterioration. The Actinic Test Site brought the cluster of ARDC locations to three in southern New Mexico.[97] The Air Force assigned the AEDD to the ARDC in May 1951, with redesignation as the Arnold Engineering Development Center at the end of July—sustaining its original acronym of AEDC from its conception as the Air Engineering Development Center in 1945.[98]

Throughout 1951, the ARDC continued to mature, sometimes acquiring entire test locations, and other times acquiring units at installations with larger missions. The Air Force assigned the Long-Range Proving Ground Division at Patrick Air Force Base in Florida, to ARDC as of mid-May 1951. ARDC redesignated the division as its Air Force Missile Test Center the next month.[99] In June 1951, Headquarters ARDC moved from Wright-Patterson to Baltimore, following an Air Force decision to place the command headquarters physically within the Boston-D.C. corridor of scientific expertise.[100]

During the year ARDC also initiated its organizational shift to Air Development Centers, with two in place before the close of the year: the Rome Air Development Center (RADC) and the Wright Air Development Center (WADC). (The Air Development Force had predated the WADC at Wright-Patterson in the lineage of that center, and had included the Weapons Components, Aeronautics, and Research Laboratory Divisions.[101]) As of 1 December 1951, ARDC had consolidated the former R&D test sites of Air Materiel Command at six installations: the Air Force Cambridge Research Center (a name change of mid-year), the RADC, the AEDC, the WADC, the Air Force Missile Test Center, and the Air Force Flight Test Center (Edwards).[102] By late in the same month the command added a seventh R&D location, with the Air Force Armament Center at Eglin brought under its jurisdiction (Plate 12).[103] Test facilities and experimental wings continued to be present at Holloman Air Force Base, but ARDC delayed its formal designation as an Air Development Center until October 1952. During the interim months, ARDC placed Holloman hierarchically beneath the Air Force Missile Test Center at Patrick. As ARDC's network of test centers grew, the command subsumed each R&D location under the WADC at Wright-Patterson, and over time the WADC remained the single largest center. The WADC was reflective of Wright-Patterson's past role as the headquarters base for the R&D mission of Air Materiel Command and its predecessors.[104]

The new command continued to reabsorb installations that had been within the R&D cluster for Air Materiel Command since the late 1940s, reconfiguring others to make them more effective. As of April 1952, the Air Force reassigned Kirtland Air Force Base to ARDC, ending the Air Force Special Weapons Command and creating the Air Force Special Weapons Center under ARDC (Plate 13). In July, Indian Springs Air Force Base near Las Vegas and the Nevada Proving Ground (Nevada Test Site) also transferred to ARDC through its ties to Kirtland. Indian Springs served as the airfield for atomic tests and was thus strongly affiliated with Kirtland's R&D mission.[105] The Air Force next transferred the Watson Laboratories in New Jersey from ARDC to the Army, focusing its electronics and upper air research missions at the Cambridge Research Center in Boston. Added in August 1952 was the Human Resources Research Laboratories at Bolling Air Force Base in Washington, D.C.—although its exact place in the evolving command was as yet undetermined. The Human Resources Research Laboratories had previously existed as a field extension of the Deputy Chief of Staff / Development at Headquarters Air Force.[106] Also by 1952, ARDC acquired the former intelligence unit T-2, which had become the Intelligence Department at Wright-Patterson with the abolishment of the T system in 1947-1948. ARDC elevated the unit to the status of a center, the Air Technical Intelligence Center (see Plate 13). ARDC's intelligence center was the predecessor of the Foreign Technology Division of 1961 and the National Air and Space Intelligence Center of the middle 1990s forward.

Where and how the overall air technical intelligence mission actually fit within Air Force structure remained vague during the early 1950s, although it was strongly affiliated with ARDC. Nearly simultaneously with the inclusion of the Air Technical Intelligence Center under an ARDC hierarchy, the center became linked to the United States Air Force Security Service (USAFSS) (later renamed the Electronic Security Command in 1979 and then the Air Force Intelligence Command in 1991, today's Air Intelligence Agency). The USAFSS derived from the Army Security Service in Virginia, an agency that had accommodated a link to the Directorate of Intelligence at Headquarters Air Force by late 1947. As of 1949, the Air Force established the USAFSS at Brooks Air Force Base in San Antonio, with a permanent location pending at nearby Kelly Air Force Base in the same city. Headquarters USAFSS would occupy Security Hill at Kelly, with construction of the needed facilities between the summer of 1951 and late 1953. By mid-January 1953, ARDC included 10 major organizations under its umbrella, located at nine physical locations. As 1953 ended, ARDC no longer included the Air Technical Intelligence Center on its organization charts, a development simultaneous with the full emergence of Headquarters USAFSS at Kelly.

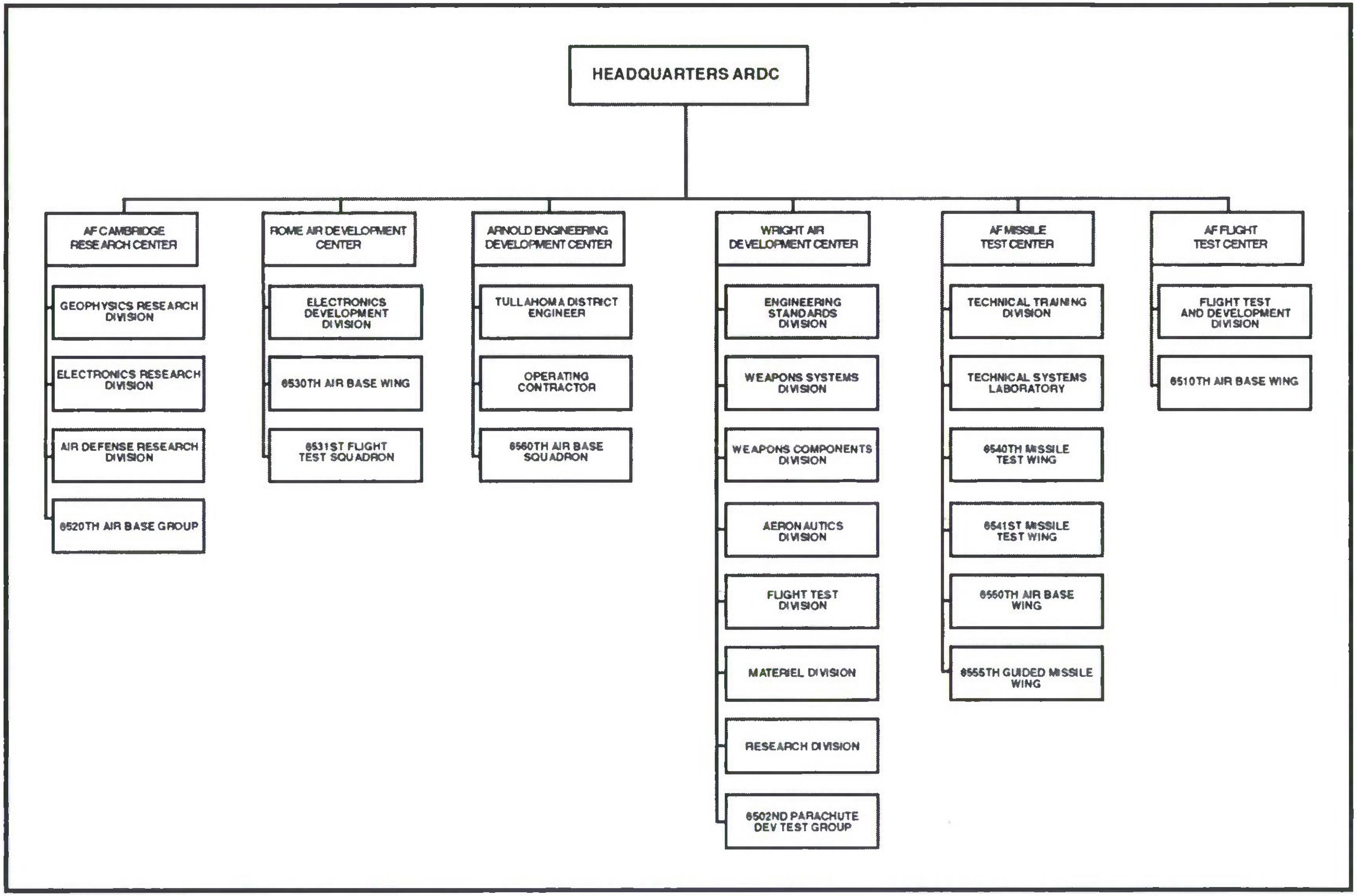

Plate 12: **ARDC Organization Chart, December 1951. Adapted from** ***Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*****, volume 1.**

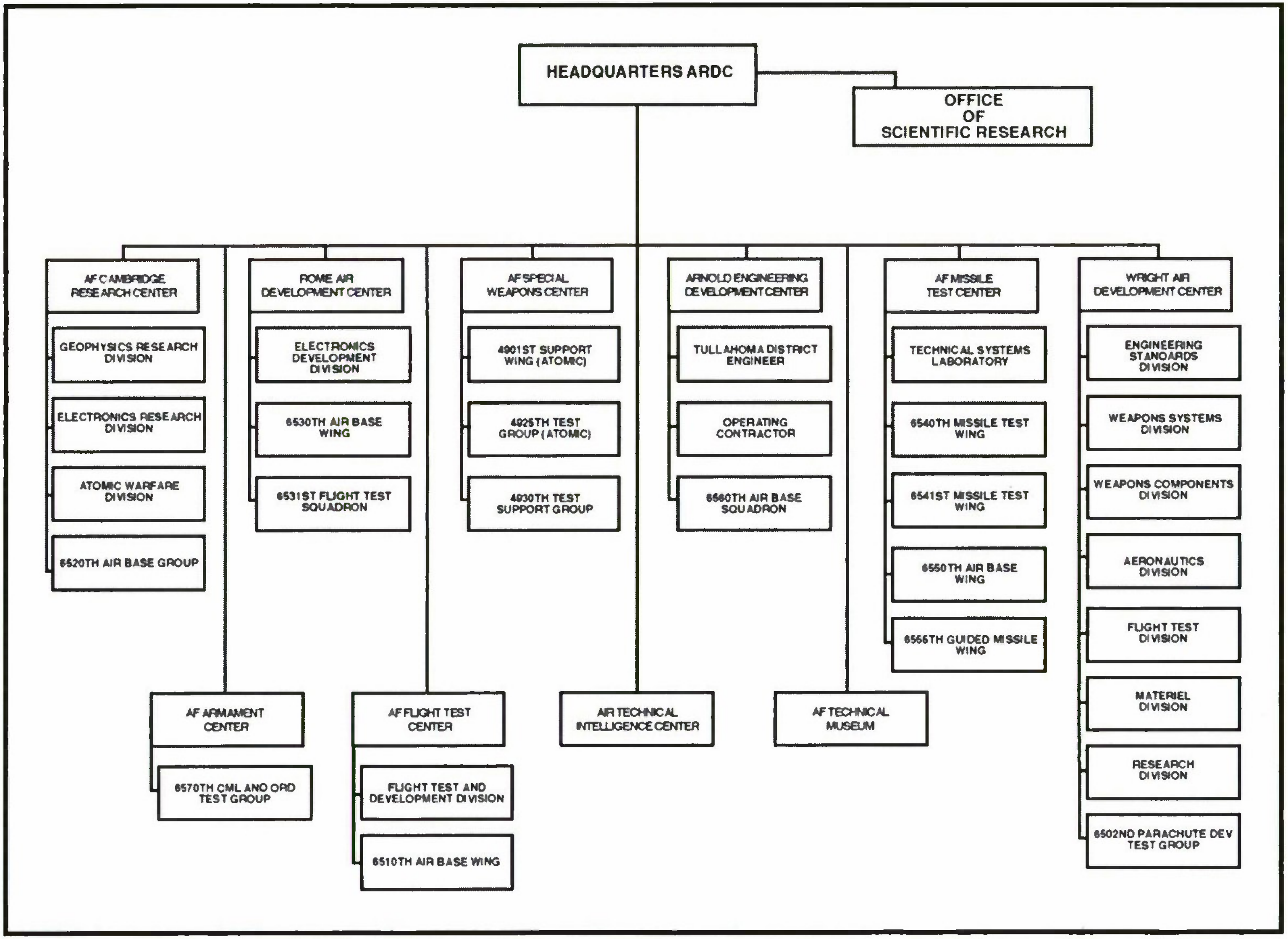

Plate 13: **ARDC Organization Chart, 15 March 1952. Adapted from** ***Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*****, volume 1.**

The Intelligence Department had evolved toward distinction as a center through the Armed Services Technical Information Agency (ASTIA) and an Air Force Technical Museum (both at Wright-Patterson).[107] The department provided the Air Force with a comprehensive "air technical and scientific intelligence service which would aid in air preparedness and air operations planning and would keep this nation from being surprised by technological developments of hostile countries."[108] Intelligence had as its ancestor the foreign (German) scientist program of the immediate post-World War II years, but by late 1949 had recognized

> the uselessness of producing bulk intelligence about all countries. It seemed that the United States had but one likely opponent in any future war, the Union of Soviet Socialist Republics. Therefore, the department determined to concentrate all of its technical intelligence activities upon the collection and evaluation of Russian information and materiel.[109]

Early in 1950, air technical intelligence included three personnel categories through the department: "investigators, analysts, and interrogators," with personnel sought "from among the reserve officers and from universities and industrial concerns." As of late June the same year, Wright-Patterson's Intelligence Department further supported five air technical intelligence reserve units at its own base, as well as in Washington, D.C.; New York; Cleveland; and, Los Angeles. The Intelligence Department of 1950 sustained ties to the State Department and the Central Intelligence Agency, with activation of foreign air technical liaison offices during the year as well. Outbreak of the Korean War in late June had fostered enhanced intelligence activities. By 1951, "a ring of offices had been forged around the Soviet zone of control."[110] Of equal note, the original link between aeronautical intelligence and the German scientist program under Project Paperclip reemerged as Project 63—an "accelerated Paperclip" approved by the Joint Chiefs of Staff in November 1950 with the explicit goal of "denying" German expertise to the Soviets. The Air Technical Intelligence Center sponsored recruitment teams to Germany during 1951 and 1952, for yet another sweep of top scientists and engineers. Recruitment continued at a slowing pace after the Korean War concluded, with another episode in November 1955. (As a part of the middle-1950s effort, the Army Ballistic Missile Agency [ABMA] at the Redstone Arsenal in Huntsville, Alabama, had sent a staff member to Germany, interviewing 93 scientists for possible recruitment. The ABMA planned to send its own agency team to Germany a second time in June 1956 for the same purpose.[111]) German scientists and engineers arrived in the United States into 1958 under the programs spurred by Korea (see Volume I, Part III).[112]

By 1953 ARDC became a fully established command, with a web of installations and test sites in place, and with clear distinctions in its management and organization from its origins within Air Materiel Command. The year before, ARDC had initiated plans for a new headquarters complex in Baltimore and directly oversaw full-scale installations. Physical master planning activities had gone forward for the Cambridge Research Center, with a move to Hanscom Air Force Base northwest of Boston. Master planning for buildings, structures and runways was also underway for the AEDC in Tennessee; as well as for Edwards, Griffiss, Holloman, Indian Springs, Kirtland, and Patrick Air Force Bases.[113] The ARDC headquarters complex took up temporary quarters in two existing early 20th century buildings in downtown Baltimore, with additional space leased for storage at another location (Plate 14).[114] The Army Corps of Engineers let a contract to Lawrie & Green of Harrisburg, Pennsylvania, to design the permanent command headquarters, after a study of 20 sites in the Baltimore area. The final site, known as Site 11 and located on the then-new Baltimore-Washington Highway at the edge of the Baltimore airport, featured a nine-story office building as of mid-decade (Plate 15).[115]

Plate 14: Headquarters ARDC, Sun & Hillen Buildings, Baltimore, ca.1953-1955. In *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

Plate 15: Headquarters ARDC, Site 11, Baltimore, ca.1956. In *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

At the close of 1953 ARDC had arrived at its mature organizational configuration, with construction advancing at most of its installations. Paralleling the expansion of ARDC, and tied to the mission of the command, were activities at Headquarters Air Force and within other Air Force commands. Subsumed beneath the Air Force Chief of Staff and focused on aeronautical R&D was the SAB and a Deputy Chief of Staff, Development. Four commands with significant R&D missions reported to the Deputy Chief of Staff, Development: Alaskan Air Command, with its Arctic Aeromedical Laboratory; ARDC; the Air University at Maxwell Air Force Base in Montgomery, Alabama, with its School of Aviation Medicine; and, the Air Proving Ground Command at Eglin, with its mission of operational suitability testing. Ten major R&D centers (several with ancillary test sites), a research institute, and a laboratory complex fed into ARDC (Plate 16): the Air Force Armament Center (at Eglin); the Air Force Cambridge Research Center (at Hanscom); the Air Force Flight Test Center (at Edwards); the Air Force Missile Test Center (at Patrick); the Air Force Special Weapons Center (at Kirtland, with support at Indian Springs); the Human Resources Research Center (at Lackland Air Force Base in San Antonio); the AEDC (in Tennessee); the Holloman Air Development Center (HADC); the RADC (at Griffiss); the WADC (at Wright-Patterson); the Human Resources Research Institute (at Maxwell); and, the Human Factors Operations Research Laboratories (at Bolling).

The coalescent maturity of ARDC in 1953 was nowhere more prominent than in the space and aviation popular press. *Aviation Week*, a journal that has always been both a good source of general information for the public and a consistent platform for military information leaks, devoted nearly its entire issue of 17 August 1953 to the command. The Air Research and Development Command edition ran about 330 pages, with interspersed advertisements placed by the aircraft and weapons industries. Having served on the Anderson Committee in 1949, Lieutenant General Putt, Commander of ARDC in 1953 and spokesman on behalf of aeronautical R&D since his days as Chief of the Experimental Bombardment Aircraft Branch at Wright Field during World War II,[116] provided a "Message from ARDC" as a preface for the stand-alone issue. Examples of technical achievements presented in the *Aviation Week* issue also appeared more formally at this same time in a publication of Headquarters ARDC: *U.S. Air Force Research and Development Accomplishments in 1952: A Special Report.*[117] Lieutenant General Putt credited future air progress to "the teamed effort of government, science, and industry."[118] Early in the article was a map illustrating the major physical locations of the new command, including its Baltimore headquarters; the 12 centers, human resources institute and human factors laboratories; the command's key climatic test sites (with that at Eglin not separated from the Air Force Armament Center); two special squadron locations; four intelligence field liaison offices (further blurring the organization of aeronautical intelligence); a European Research Office in Brussels, Belgium; and, the beginnings of what would become an ICBM R&D mission in Los Angeles through the Office of Scientific Research, Western Regional Office, in Santa Monica (Plate 17). Illustrated key climatic test installations were those of the Arctic Aeromedical Laboratory at Ladd Field, Alaska; the All-Weather Test Station at Ypsilanti, Michigan (subsumed within WADC and a continuous enterprise from the 1950 Willow Run facility—the test station also known as the Aeronautical Ice Research Laboratory); and the Mount Washington Test Facility at Gorman, New Hampshire (sometimes referenced as ARDC's Climate Project Laboratory). The two special squadrons were those at Indian Springs for the atomic test mission (connected to the Air Force Special Weapons Center at Kirtland) and a parachute development test group at El Centro, on the border between California and Arizona. The parachute test facility dated back to the 2752nd Experimental Group located at the Naval Auxiliary Air Station and associated with ARDC as of spring 1951. The four intelligence liaison offices were directly tied to the Air Technical Intelligence Center at Wright-Patterson and the USAFSS at Kelly, and featured locations in Tokyo, Los Angeles, Washington, D.C., and New York.[119]

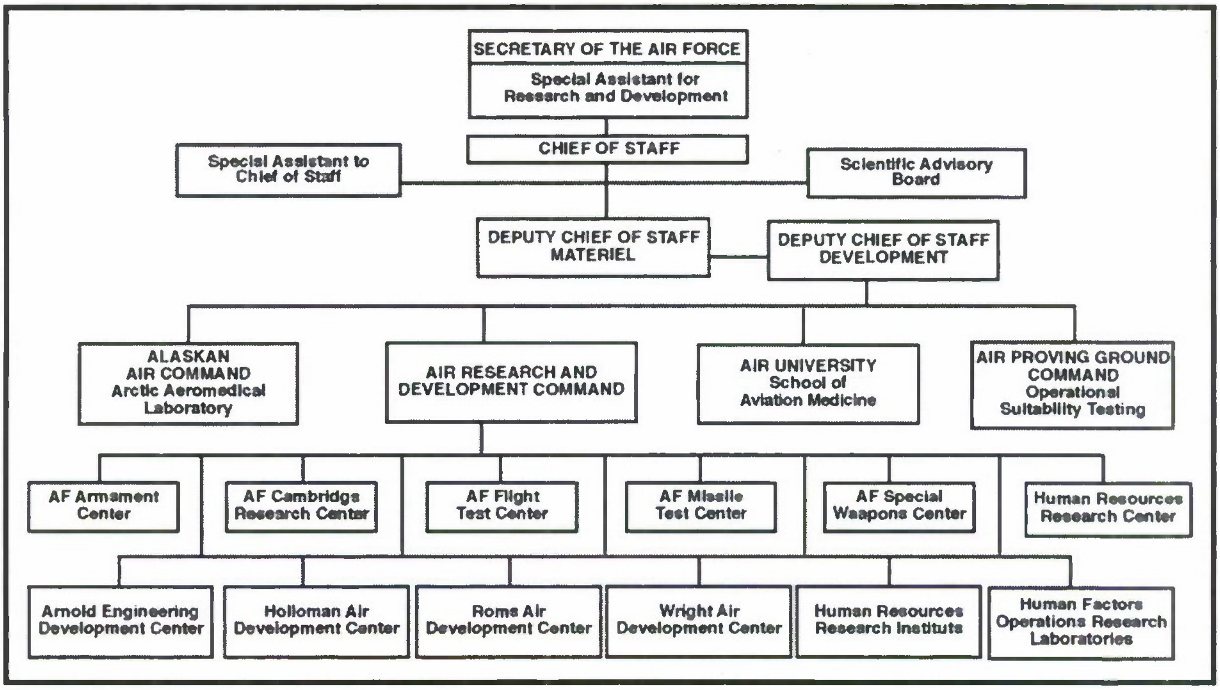

Plate 16: Organization for R&D in the Air Force, 31 December 1953. In *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

Lieutenant General Putt further extrapolated the mission of ARDC.

> ARDC's job is not to actually do the research and development...For that we rely primarily on industry, universities, and civilian research organizations. Our job is to tell these groups the problems the Air Force wants to solve and to program, finance, monitor and evaluate the work necessary to solve them. In turn we keep the Air Force informed on the kind of equipment they are likely to get at any given time because of the 'state of the art' in any particular field.[120]

The article noted that ARDC's mission fell into the three broad categories of basic research, applied research, and testing. The Office of Scientific Research (coupled with the SAB and placed interchangeably with it on Air Force R&D organization charts) handled the basic research efforts, chiefly through contracts to university scientists and civilian research organizations. ARDC announced its applied research as 85% contracted, with the remaining 15% carried out by the laboratories at WADC, RADC, and the Cambridge Research Center. The other ARDC installations orchestrated assigned testing, although the command also had the responsibility for revising and approving manufacturers' engineering specifications for all Air Force equipment and for resolving all technical complaints on equipment procured through Air Materiel Command's AMAs. The latter task funneled through WADC, and was a remaining link between ARDC and Air Materiel Command.[121]

The planners of ARDC organized the command headquarters to functionally parallel that of the Air Force itself, and in this sense ARDC stood quite apart from its sister commands within the agency. In addition to the Office of Scientific Research—a basic research unit with no counterpart in the other Air Force commands—ARDC also featured an Office of the Assistant for Operational Readiness and

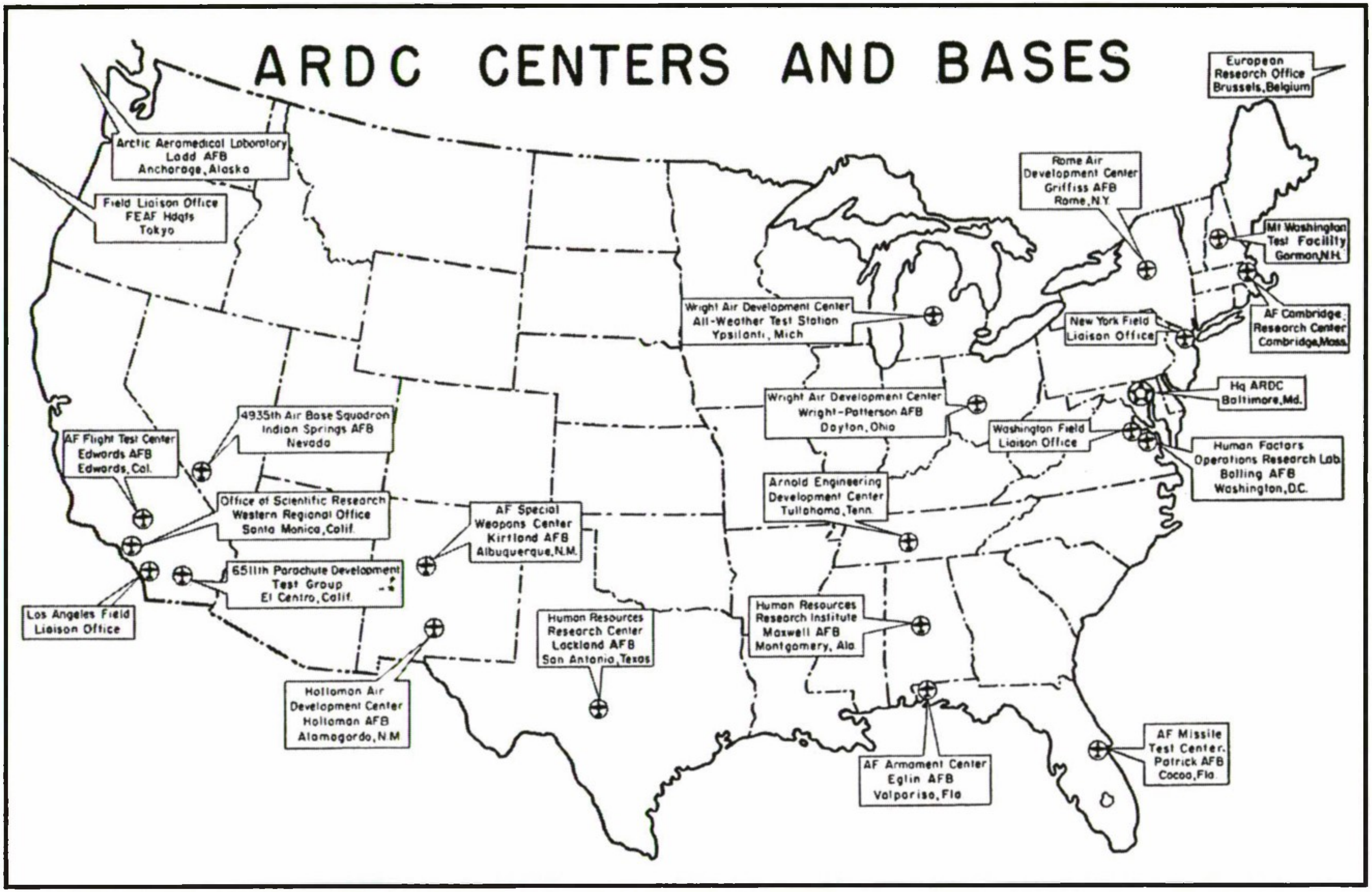

Plate 17: ARDC Centers and Bases. In *Aviation Week*, 17 August 1953.

one for the Deputy of Development, all three tied directly to Headquarters ARDC. The Operational Readiness office coordinated what were termed "readiness teams." These ARDC personnel teams worked with each of the Air Force commands to ascertain needs and to keep the commands abreast of technical possibilities. These teams coordinated directly with SAC, Tactical Air Command (TAC), Air Defense Command (ADC), Air Training Command (ATC), and Military Air Transport Service (MATS). In at least the cases of SAC, TAC, and ADC, ARDC conducted vital research and experimentation toward major civil engineering achievements in hardened infrastructure and in the electronics systems required for modern-era air defense. The Deputy of Development, in a function side by side with that of Operational Readiness, managed the technical programs of ARDC that applied to SAC (strategic combat systems), TAC (tactical combat systems), ADC (air defense systems), and ATC (air logistics and training systems). ARDC systems development for reconnaissance, intelligence, and psychological warfare were spread across each of the four commands, with ARDC efforts for MATS more generically applied.[122]

Of the physical installations and test facilities mapped in the *Aviation Week* presentation of August 1953, three field stations were new to the command during 1952-1953, and illustrated an emergent sophistication indicative of the unfolding Cold War. At the outset of the decade aeromedical studies within Air Materiel Command had already begun to focus on psychological research. One small example of the nascent sophistication was "shape coding." Distinctive shaping of pilot aircraft controls allowed more efficient, positive user identification under all circumstances.[123] By 1953, these kinds of efforts had expanded significantly. The three R&D field stations of this type within ARDC were those of the Human Resources Research Institute at Maxwell; the Human Resources Research Center at Lackland; and, the Human Factors Operations Research Laboratories at Bolling. The institute at Maxwell, commanded by Major General Franklin O. Carroll, concentrated on cultural research with special focus on psychological warfare, strategic intelligence, counter-intelligence, and morale. Major General Carroll had headed up the Experimental Engineering branch at Wright Field during World War II, and had initiated a study of cold-weather aircraft and equipment testing that led to the Arctic, Desert and Tropic Information Center at Eglin and then to the climatic hangar there. The Arctic, Desert and Tropic Information Center approached extreme-weather testing in a sophisticated manner that stressed backgrounds in multiple disciplines, including anthropology, ethnology, and psychology, and further emphasized the value of foreign language expertise. Ph.D.s at the Arctic, Desert and Tropic Information Center numbered 18; Master's degrees, six. Some members of the staff were fluent in four languages, a few men in a half dozen. Overall language capabilities included 20 non-English tongues.[124] The backgrounds and education levels present in the staff at the Arctic, Desert and Tropic Information Center foreshadowed a sharp Cold War turn to psychological warfare studies. The other two related field stations handled psychological research toward personnel placement and training (the Human Resources Research Center at Lackland) and the evaluation of human factors under operational conditions (the Human Factors Operations Research Laboratories at Bolling).[125]

Aviation Week continued its unveiling of ARDC with a full-length presentation on each of the 12 centers supporting the command. The journal also discussed ancillary sites and non-Air Force operations linked to the ARDC mission. These included the atomic test locations at the Nevada Proving Ground and in the Marshall Islands for the Special Weapons Center at Kirtland—both operations supporting the Atomic Energy Commission (AEC); the presence of NACA and aircraft contractors for flight research tenant missions at the Flight Test Center at Edwards; auxiliary installations for the Missile Test Center at Patrick to accommodate the study of long-range missile launches (in the Dominican Republic, Puerto Rico, and on Grand Bahama, Eleuthera, San Salvador, Mayaguana, and Grand Turk islands in the Bahamas); and, off-base radar test sites for RADC at Forestport, Newport, Floyd, and Verona, New York, as well as navigation test facilities at Adamston, New Jersey; Carrabelle, Florida; and, Cape Fear, North Carolina.

Also listed were multiple ARDC field offices at other military and university locations. Administered by Headquarters ARDC in Baltimore, these links included ones for the Army, the Navy, and NACA. Within the Army were:

- the Engineer Research and Development Laboratories at Fort Belvoir, Virginia (including a United States Air Force Engineering Field Office on site);
- the Army Field Forces Board No. 1 at Fort Bragg, North Carolina;
- the Armed Services Electro Standards Agency and the Signal Corps Engineering Laboratory, both at Fort Monmouth, New Jersey;
- the Aberdeen Proving Ground, and neighboring Army Chemical Center in Maryland; and,
- the Chemical Corps Biological Laboratories at Camp Detrick, Maryland.

For the Navy, direct ties to ARDC existed at:

- the Naval Research Laboratory (NRL), in Washington, D.C.;
- the Naval Air Test Center, at Patuxent River, Maryland;
- the Naval Air Development Center, in Johnsville, Pennsylvania;
- the Naval Air Missile Test Center, at Point Mugu, California;
- the Naval Ordnance Test Station, at China Lake, California; and,
- the Naval Construction Battalion Center, at Port Hueneme, California (by 1959 known as the Naval Civil Engineering Laboratory [NCEL]).

While NACA's parallel R&D sites (also exchanging information with ARDC) were:

- the Aeronautical Laboratory, at Langley Air Force Base;
- the Ames Aeronautical Laboratory, at Moffett Field, California; and,
- the Lewis Flight Propulsion Laboratory, in Cleveland, Ohio.

Additionally supporting ARDC were field offices at Johns Hopkins University in Baltimore and MIT in Boston.[126]

Two other key missions were emerging within ARDC during 1953 that would each come to be associated with its own installation by the early 1960s. *Aviation Week* explored one of these, aviation medicine, in depth.[127] The aeromedical mission of ARDC during its first years focused on the ability "to put a man in an airplane and to keep him alive,"[128] with airplanes shifting to space launch vehicles as time moved forward. The Aero Medical Research Laboratory at WADC worked on the problems of temperature and pressurization in crew compartments; high-altitude garments, including anti-G suits; acoustic noise control; efficient flight simulators; and even, inflight meals. Experimental flights of Bell Aircraft's X-1 at Edwards proved that pressurized pilot suits which inflated with a loss of cabin pressure automatically, saved lives at the very high test altitudes then sought. The Aero Medical Research Laboratory also developed an "exposure" suit to protect the pilot from immersion in icy water or very hot cabin air. The V-3 exposure garment was a double-shelled suit that used an inner layer of woven Saran plastic, with ventilating tubes to circulate air. Synthetic wonder materials—especially plastic—pointed the way to other aeromedical innovations, and soon the laboratory took on the medical challenges associated with many broader aspects of modern warfare. Another example was the development of Aeroplast, a material also plastic-based. Aeroplast featured an aerosol spray kit that could cover burned areas with a thin layer of plastic quickly and effectively, replacing bandages. Assumptions for Aeroplast's value were not those of traditional warfare, but instead denoted a Cold War impetus: "In civil defense...there will not be enough bandage available to cover the hundreds of thousands of burn cases expected from atomic explosions."[129] Specialized

equipment, and facilities to house that equipment, too, became a hallmark of the science required for the unfolding aeromedical mission. From the beginning, a variety of high-altitude test chambers, centrifuge machinery, ejection towers, air locks, vibration tables, all-weather units, and anechoic rooms (using another wonder material, Fiberglas) augmented the aeromedical testing. While an aeromedical laboratory mission at Wright Field dated to the middle 1930s, as a part of the Army's Physiological Research Unit, the importance of aeromedical R&D grew very rapidly during the first decade of the Cold War. Efforts focused at Wright-Patterson and in San Antonio. At Lackland aeromedical R&D first advanced at the existing School of Aviation Medicine, and then at a laboratory complex set up at Brooks as of 1959.

Aviation Week only alluded to the other nascent mission of ARDC, that of the ballistic missile program. As of October 1951, the Air Force had created Weapons Systems Project Offices (WSPOs) for the management of weapons acquisition, including missiles. The Air Force staffed these field units with personnel from both ARDC and Air Materiel Command. Predictably during 1952, ARDC claimed more control over weapons development, stimulated by the command's knowledge of Soviet weapons progress. The next year, the Secretary of Defense requested a review of the missile programs running concurrently among the three American military services. As of the outset of 1954, an ICBM program within the Air Force became much more directed with the creation of the Western Development Division (WDD)—the field office successor of the Western Regional Branch of the Office of Scientific Research of the year before. The WDD was a formal field station of ARDC charged with ICBM development.[130] Subsequent refinements and expansions of the WDD would elevate the ICBM R&D unit of ARDC to nearly the status of an installation, although the evolution of the WDD was wholly different from that of typical installations. (Through name changes, as well as complicated splits and regroupings, the WDD's successors became Los Angeles Air Force Base in the late 1980s.) This particular ARDC facility would always be contractor-focused, with strong ties to Vandenberg and Patrick Air Force Bases (the latter including the launch sites at Cape Canaveral Air Force Station). The 17 August 1953 issue of *Aviation Week* mapped the Western Regional field station of the Office of Scientific Research in Santa Monica, the earliest iteration toward the WDD (see Plate 17). In addition the journal included the first insignia of ARDC, a design that interpreted missiles as the key symbol of the future and one that made missile imagery its centerpiece (Plate 18).

While the late 1953 structure of ARDC remained definitive for most of the decade, the tensions between ARDC and Air Materiel Command never fully resolved themselves. Multiple studies occupied committees within the command, seeking to better clarify the relationships between basic Air Force R&D and procurement—the latter including service engineering. Significant reports included those of the Kirk Committee (October 1951), Lawhon (February 1954), Williams (June 1954), Rader (July 1955), Sinex (March 1957), Grek (June 1957), and Drysdale (October 1957), with additional discussion in the *Report on Research and Development of Guided Missiles and Space Vehicles over the Time Period 1955-1957*. Partially resulting from the steady reviews of the 1951-1957 years, Headquarters ARDC moved from its independent office complex in Baltimore (see Plate 15) back to a physical location at an Air Force installation. As of late January 1958, Andrews Air Force Base, immediately outside Washington, D.C., in Camp Springs, Maryland, hosted Headquarters ARDC (Plate 19).[131]

Overlapping the shift of Headquarters ARDC to Andrews, the SAB conducted a study of Air Force R&D through its Ad Hoc Committee on Research and Development. The Air Force Chief of Staff, General Thomas A. White, had charged the SAB with its assignment in November 1957, and the Ad Hoc Committee on Research and Development presented its recommendations to General White in June 1958. Among its findings, the SAB argued for a new organizational structure for the ARDC mission and for changes to R&D policy, resource allocation, and program activities at the Air Staff level. The SAB recommended that a smaller set of functionally organized divisions with a more

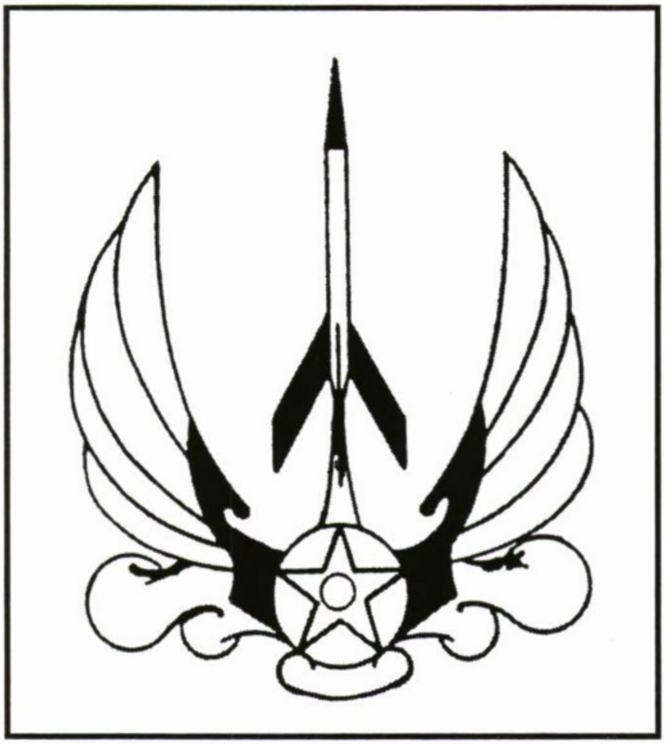

Plate 18: ARDC Insignia, August 1953. In *Aviation Week*, 17 August 1953.

decentralized jurisdictional management replace a geographic constellation of test centers and facilities tiered to a centralized headquarters. In addition, the SAB called for a deputy commander in charge of four R&D areas: research, technical development, weapons systems, and testing. Headquarters ARDC would eliminate those programs that overlapped field operations. Known as the Stever Report, due to the heading of the committee by Dr. H. Guyford Stever, an MIT physics professor who then served as Chief Scientist of the Air Force and who would later chair the SAB, the document found favor with both the Air Staff and Headquarters ARDC. The command used the Stever Report to propose its own guidelines for reorganization.[132]

As these recommendations percolated within the Air Force, ARDC was also in the midst of a change of commander. The new man, Lieutenant General Bernard A. Schriever, came from the WDD, where he had headed ARDC's ballistic missile efforts since inception of the division. (By mid-1957 the WDD had become the AFBMD.) In mid-1959, Lieutenant General Schriever had the results of yet another study (that of the Maxwell Committee), and superimposing his experience with the WDD / AFBMD onto the larger organizational challenges of the ARDC, he acted on its findings. The restructuring of Air Force R&D replaced the existing organization with four divisions as of late 1959: the AFBMD, in Los Angeles, for missile and space programs; the Wright Air Development Division (WADD) for aeronautical systems (with the WADC discontinued); the Air Force Command and Control Development Division (AFCCDD), at Hanscom, for electronics research (evolved directly from the Air Defense Systems Management Office of 1957 and the Air Defense Systems Integration Division of 1958);[133] and, the Air Force Research Division (AFRD) in Washington, D.C., for basic R&D.[134] The Schriever reorganization elevated hierarchical units at Headquarters ARDC; Wright-Patterson and Hanscom Air Force Bases in Ohio and Massachusetts; and, the AFBMD in Los Angeles to a level on a par with one another, delineating the remaining R&D centers as somewhat separate and subordinate. Individual laboratories continued to exist, although with name

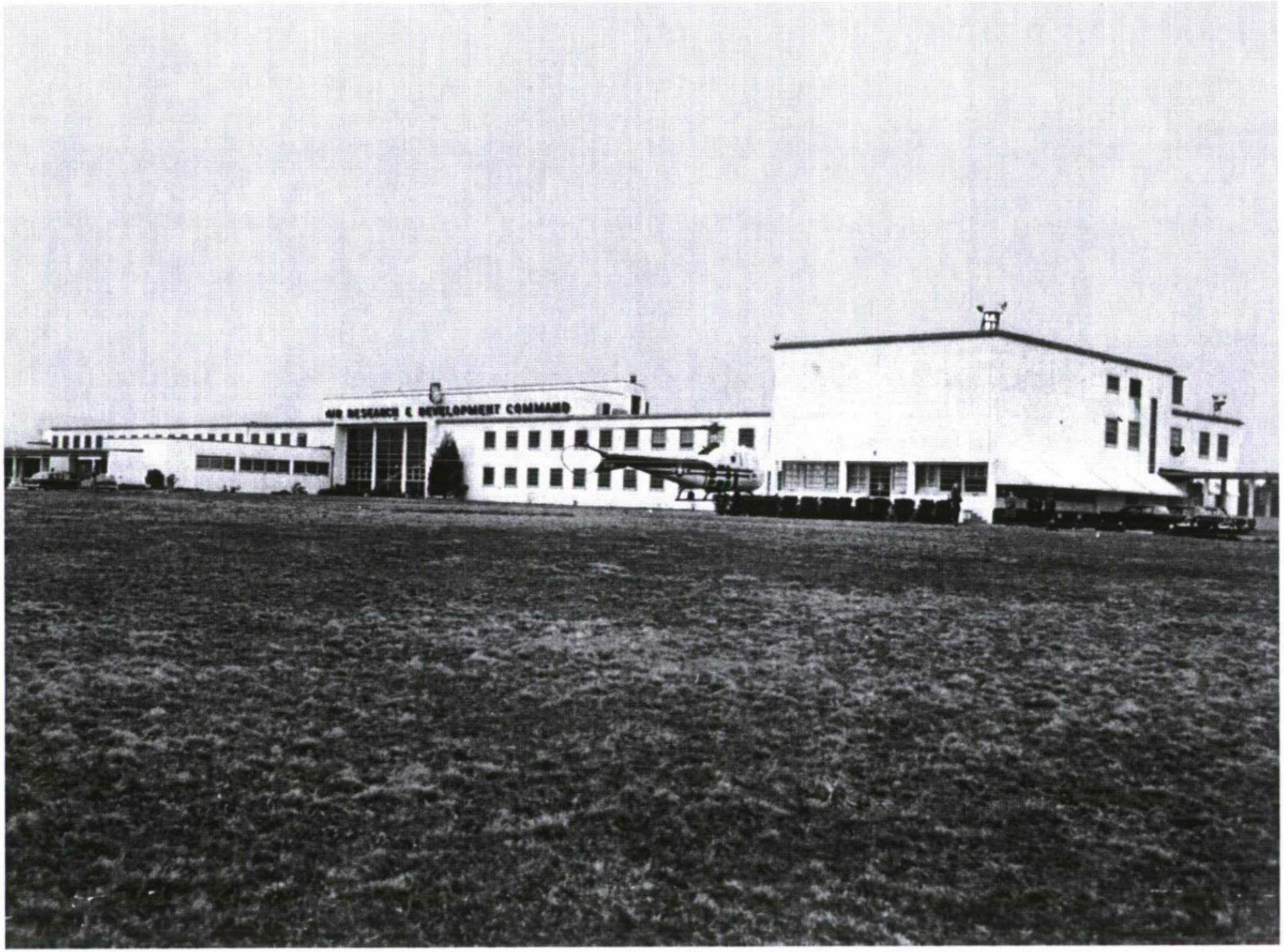

Plate 19: Headquarters ARDC, Andrews Air Force Base, Maryland, 1958. In *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

and assignment changes. The Cambridge Research Center, for example, became the Cambridge Research Laboratories in August 1960, assigned to the AFRD and returning to its name of 1949-1951.[135]

Management of weapons systems development, particularly that of ballistic missiles, was yet another factor that affected the organizational restructuring for Air Force R&D in the late 1950s. Air Force Vice Chief of Staff, General Curtis LeMay, insisted upon a reassessment of the cradle-to-the-grave process for new weapons systems, and thus again raised the old issues about where and how the R&D and procurement missions dovetailed and overlapped. ARDC desired full control over the weapons acquisition process, and several differing program changes between ARDC and Air Materiel Command were under sequential review. The commander of ARDC, General Schriever, and of Air Materiel Command, General Samuel Anderson, countered each other's proposals for the preferred reorganization, with General Schriever arguing in April 1960 for a split between the two commands at the "point of logistics support." Schriever suggested that "people engaged in weapons acquisition developed analytical patterns of thought and learned to live with calculated risks; logisticians, on the other hand, acquired empirical, conservative habits of mind."[136] General Anderson favored an opposite tack. He desired to merge the two commands back together to solve the weapons systems development dilemmas. By mid-1960, upper Air Force leaders rejected both ideas, and review of the two commands continued. In addition, the American space program and the space race with the Soviet Union began to shape reorganization thought by early 1961.[137]

Under Air Force Systems Command: 1961-1992

At the end of March 1961, ARDC still featured a structure of 12 major units, adapting the ideas presented for reorganization over 1959-1960 but essentially remaining the same as earlier in the decade (Plate 20). Four divisions, as set forth in the Maxwell findings of late 1959, reported to the commander and vice commander of ARDC. The RADC became a direct adjunct of AFCCDD, thus achieving what had been intended all along—that the Rome laboratories be subsumed under those of Cambridge at Hanscom. The six remaining centers, Missile Test (Patrick), Missile Development (Holloman—which had undergone a name change from HADC to the Air Force Missile Development Center in 1957), Flight Test (Edwards), Special Weapons (Kirtland), the Air Proving Ground (Eglin—with the Air Force Armament Center redesignated the Armament Division, assigned to the Air Proving Ground Center), and the AEDC (Arnold), along with the ASTIA (intelligence at Wright-Patterson), also reported directly to the commander's office. As of 8 March 1961, the Department of Defense assigned comprehensive military space research to the Air Force, and within a week the Air Force Chief of Staff, General White, adopted the Schriever plan of April 1960. The Air Force changed ARDC's name to Air Force Systems Command (AFSC), and simultaneously redesignated Air Materiel Command as Air Force Logistics Command (AFLC). The two new commands became official on 1 April 1961.

The organization for AFSC differed slightly from that of ARDC in 1959, featuring a distinct headquarters and four divisions of Space Systems, Ballistic Systems, Aeronautical Systems, and Electronic Systems (Plate 21). Space and Ballistic Systems split the previous AFBMD into two divisions from one, with the expansion of the space mission a critical theme for AFSC as the 1960s unfolded. A name change for the Hanscom function within the command—from AFCCDD to Electronic Systems Division—also illustrated Air Force recognition of ADC's maturing first- and second-generation command-and-control facilities of the 1949-1960 period. The Hanscom and Rome research laboratories had largely pioneered these facilities (see Volume 1, Part IV). In addition, the designation of Electronic Systems Division pointed to the continuing overlap and complexity of shared missions between the ARDC / Air Materiel Command and AFSC / AFLC pairs. Electronic Systems Division not only evolved from the AFCCDD, but also incorporated Air Materiel

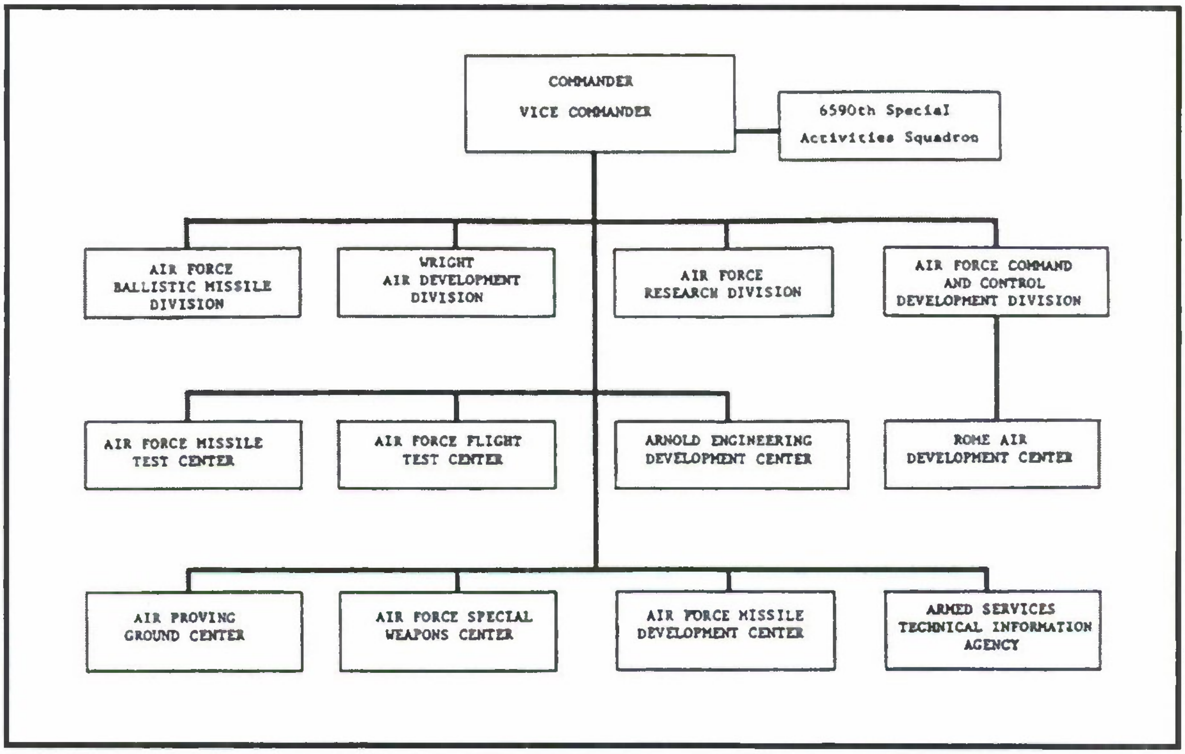

Plate 20: ARDC Organization Chart, 31 March 1961. In *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

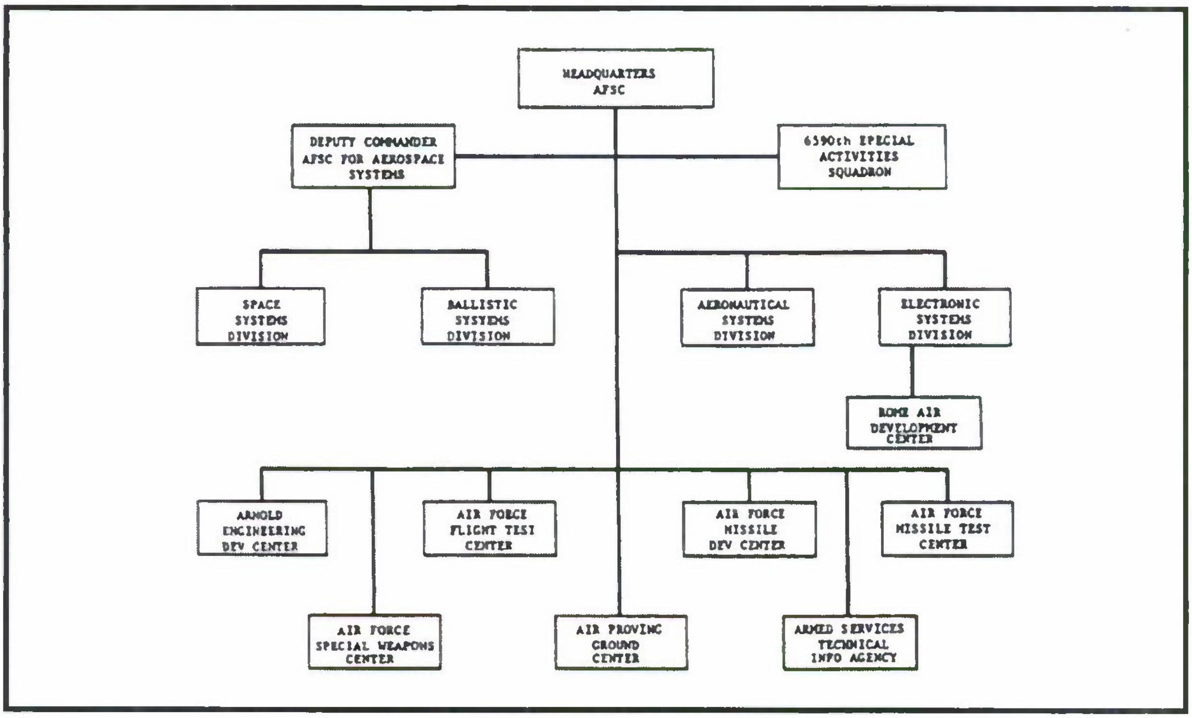

Plate 21: AFSC Organization Chart, 1 April 1961. In *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

Command's Electronic Systems Center of 1959-1961. From this point forward, the laboratories at Hanscom would turn attention to broader electronics problems. Electronic Systems Division unified the full electronics R&D mission at the installation. Similarly, Aeronautical Systems Division brought together the former WADD of ARDC and the ASC of Air Materiel Command.[138] The hierarchy of the remaining seven centers and the ASTIA stayed the same as in 1959.[139]

Command modification continued during the next decades for AFSC, but at a much reduced pace. Almost immediately, AFSC elevated the aeromedical research and intelligence missions to the division level. As of April 1961, ASTIA became the Foreign Technology Division, headquartered at Wright-Patterson. AFSC assigned aeromedical research to Brooks Air Force Base as of November 1961, establishing the headquarters for the Aerospace Medical Division there. An Air Force Aerospace Medical Center had been in place at Brooks since late 1959, with the Air Force School of Aviation Medicine located at Brooks from 1926-1931 and at neighboring Randolph Air Force Base from 1931 until the return to Brooks. With the restructuring of the aeromedical mission, the Air Force also reassigned the Arctic Aeromedical Laboratory from Alaskan Air Command to the Aerospace Medical Division at Brooks. An aeromedical research laboratory continued at Wright-Patterson, with another established at Holloman from 1961 to 1970, as subordinate units within the Aerospace Medical Division.[140] In 1961 also, an Air Force Office of Aerospace Research came into existence as a separate operating agency, with its headquarters located at Wright-Patterson. Subsumed under the Office of Aerospace Research between 1961 and mid-1970 were the Aeronautical Research Laboratory (later, Aerospace Research Laboratories) at Wright-Patterson and the Cambridge Research Laboratories at Hanscom. The Office of Aerospace Research derived directly from the AFRD of 1959.[141] In early 1962, the Research and Technology Division, Provisional, began to supplement the Office of Aerospace Research, placed at Andrews and assigned to AFSC. AFSC formalized the Research and Technology Division in July, moving the division from Andrews to Bolling Air Force Base in Washington, D.C.[142] The Research and Technology Division managed several individual laboratories, including the Aero-Propulsion, Avionics, Flight Dynamics, and Materials Laboratories at Wright-Patterson (1963-1967); the Air Force Armament Laboratory at Eglin (1966-1967); the Air Force Rocket Propulsion Laboratory at Edwards (1963-1967); and, the RADC (1963-1967).[143] The Office of Scientific Research and related European operations complemented the two laboratory clusters, bringing the idea of basic research full circle with its origins in the early 1950s.[144] Separation from Headquarters AFSC for the Research and Technology Division was due to limited office space at Andrews, with other functions also becoming "widely scattered" in the Washington, D.C., area. AFSC began to expand its headquarters complex in Building 1535 at Andrews (see Plate 19) through the addition of two wings in the early and middle 1960s.[145]

The two space-and-missile test components of AFSC moved up in the hierarchy by 1970, strongly illustrating the focus of R&D during the middle years of the Cold War. When Vandenberg Air Force Base had become operational in 1957, its first six months had gone forward under the umbrella of ARDC. SAC took over Vandenberg as of January 1958, but an ARDC / AFSC role reemerging there with the expansion of missile test needs through the AFBMD after 1959. By the middle 1960s, SAC and AFSC had split use of Vandenberg's launch facilities, with SAC conducting missile launch exercises and alerts, and AFSC performing missile and satellite launch tests over the waters of the Pacific Ocean defined by the Air Force Western Test Range (coupled with testing over the Atlantic Ocean within the boundaries of the Air Force Eastern Test Range). Both test ranges were consistently under the jurisdiction of AFSC, although the hierarchical organization varied. In 1964, AFSC had redesignated the Missile Test Center at Patrick as the Air Force Eastern Test Range, immediately assigning the range to a newly created National Range Division.[146] In early 1972, AFSC dissolved the National Range Division, but maintained responsibility for the range.[147] A similar process occurred for the Air Force Western Test Range, constituted by AFSC in 1964 at Vandenberg with

assignment to the National Range Division. As of 1970, the Air Force Western Test Range inactivated, henceforth operated as the Space and Missile Test Center (at Vandenberg) and subsumed beneath the Space and Missile Systems Organization (SAMSO) at Los Angeles Air Force Station into late 1979.[148] AFSC had reunited the Space Systems and Ballistics Systems Divisions as SAMSO in July 1967. The Eastern Test Range also came under the Space and Missile Test Center at Vandenberg as of early 1977, until the activation of the Eastern Space and Missile Center in October 1979.[149] (The Western Test Range became the Western Space and Missile Center at this same time.[150]) After August 1970, the Air Force Missile Development Center at Holloman merged with the Air Force Special Weapons Center (AFSWC) at Kirtland, shifting work at the Special Weapons Center strongly toward missiles R&D. As an installation, Holloman no longer came under AFSC, but instead moved under the command of TAC.[151]

Tiered beneath the grouped laboratories and the two space-test functions located at Patrick (including Canaveral) and at Los Angeles – Vandenberg were five divisions, with the four remaining test centers as the lowest line of the organization. The majority of the laboratories were physically sited at Wright-Patterson, but during the 1960s and 1970s AFSC began to manage its laboratories as clusters in a network across the United States, with key locations at Rome, New York; Cambridge (Hanscom); Edwards; and, Kirtland. The Air Force Weapons Laboratory (AFWL) at Kirtland was new as of 1963, formed from preexisting R&D components of the Air Force Special Weapons Center but distinct from it. (Both the Air Force Special Weapons Center and the AFWL coexisted until April 1976, when the Special Weapons Center inactivated.) The five divisions of AFSC were those of Aerospace Medical at Brooks; Air Force Contract Management at Annex 1, Los Angeles Air Force Station, and later moved to Kirtland as of October 1972 (derived from a regional contract management system of 1961, and established in 1965);[152] Foreign Technology and Aeronautical Systems, both at Wright-Patterson; and, Electronics Systems at Hanscom. The four test centers as of August 1970 were the Armament Development and Test Center at Eglin, the Flight Test Center at Edwards, the Special Weapons Center at Kirtland, and the AEDC at Arnold[153] (Plate 22).

With the inactivation of the Research and Technology Division as a formal entity in late 1967 and the Office of Aerospace Research in mid-1970, the command moved to reincorporate the grouped research laboratories into the systems acquisitions process during the early 1970s, tying the laboratories more closely both to each other and to the installations hosting them—installations that typically also hosted the divisions and centers to which the laboratories reported (Plate 23). To foster a more unified laboratories mission across the command, AFSC had created a Director of Laboratories at headquarters in March 1967, transferring the functions of the Research and Technology Division to this position in November. The personnel of the discontinued Research and Technology Division had remained at Bolling, although reported to the Director of Laboratories at Andrews. As of July 1970, the functions of the inactivated Office of Scientific Research returned to AFSC,[154] presumably absorbed into the Director of Laboratories (see Plate 22). To further facilitate cohesion at Headquarters AFSC, the command again expanded its office space in Building 1535 through the addition of a large rear wing. The finished headquarters complex resembled a hub-and-spokes wheel in its shape. An outer fan of Butler buildings mirrored the curve of the addition of 1967-1968 (Plate 24).[155] By mid-1974, AFSC structure included six divisions: SAMSO at Los Angeles Air Force Station; the Aeronautical Systems and the Foreign Technology Divisions at Wright-Patterson; Electronic Systems Division at Hanscom; the Aerospace Medical Division at Brooks; and, the Air Force Contract Management Division at Kirtland. The next tier of the organizational structure delineated four historic R&D centers—those of Armament Development and Test at Eglin, Flight Test at Edwards, Special Weapons at Kirtland, and the AEDC at Arnold—and the two missile test ranges (the Space and Missile Test Center at Vandenberg and the Air Force Eastern Test Range at Patrick).[156] Kirtland was an unusual situation, with AFSC beginning to phase out the Air Force Special Weapons Center and placing the AFWL hierarchically under SAMSO at Los Angeles Air Force Station as of 1976 (see Volume II, Chapter 8).

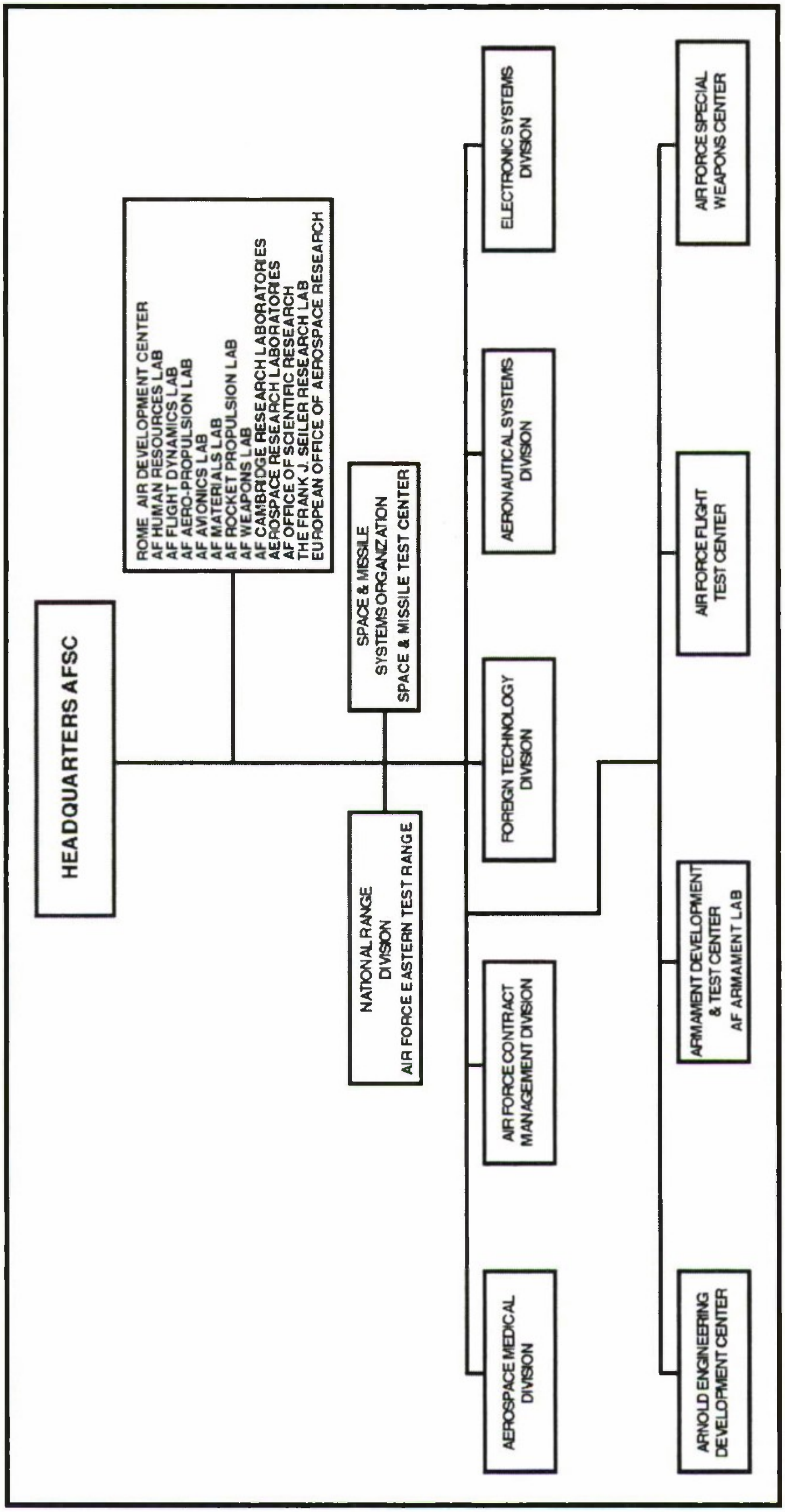

Plate 22: AFSC Organization Chart, 1 August 1970. Adapted from *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

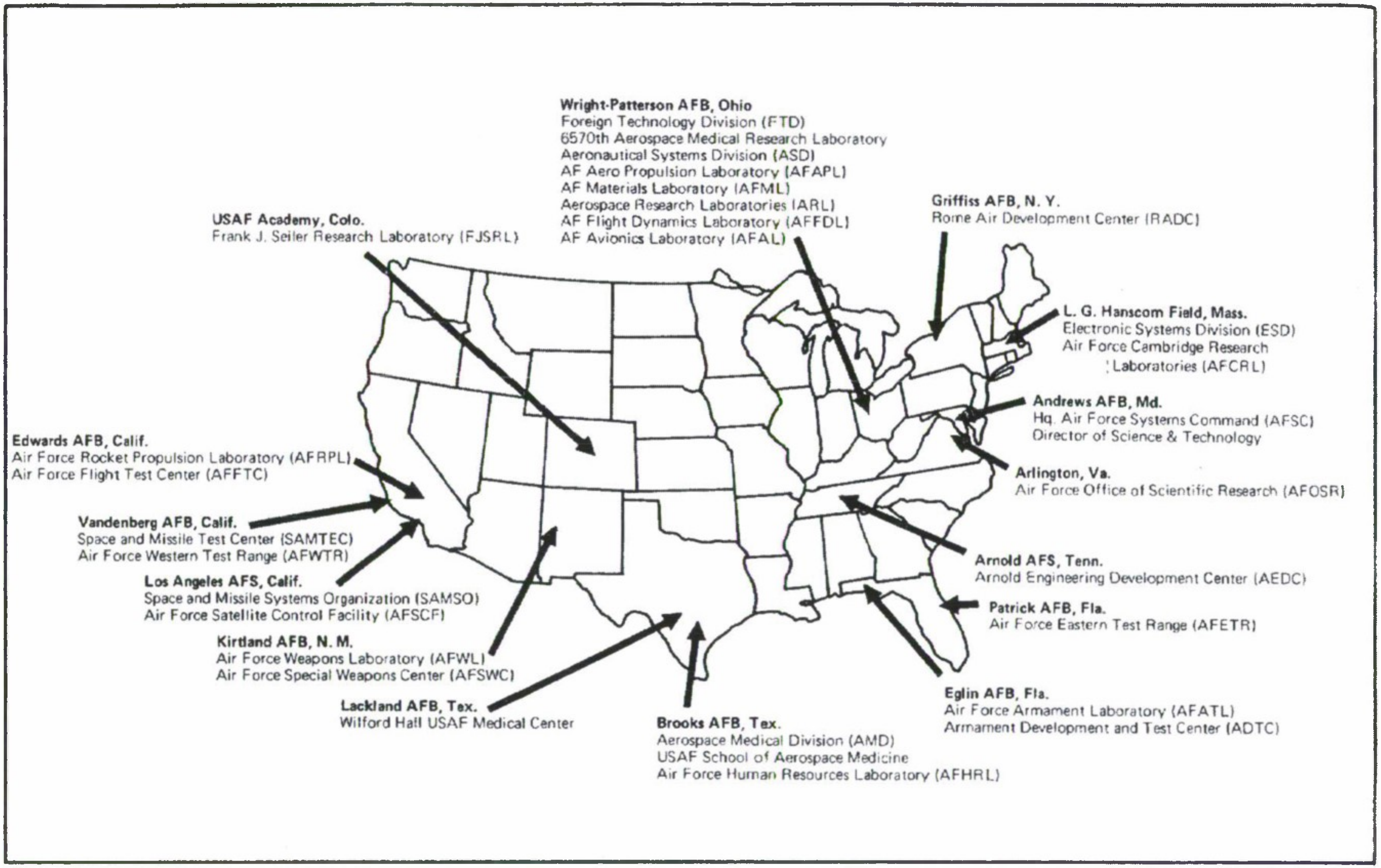

Plate 23: Key Installations in Air Force Scientific and Technological Activities. In *Air Force Magazine*, May 1973.

Plate 24: Headquarters AFSC, Andrews Air Force Base, Maryland, 1968. In *History of Air Force Systems Command 1 July 1968 – 30 June 1969*, volume 1.

At the lowest tier of AFSC were the laboratories; the Office of Scientific Research, and a newly emerged center for civil engineering (Plate 25). Laboratories included Aero Propulsion, Aerospace Research, Avionics, Flight Dynamics, and Materials at Wright-Patterson; Rocket Propulsion at Edwards; Human Resources at Brooks; Weapons at Kirtland; Cambridge Research at Hanscom; and, the Frank J. Seiler Research Laboratory at the Air Force Academy in Colorado. (The Frank J. Seiler Research Laboratory originated as the Colorado Astronautical Research Laboratory at the Air Force Academy in 1962.[157]) The command had located the Office of Scientific Research in Arlington, Virginia, in mid-1966, moving it again to Bolling in late 1975.[158] Finally, the Air Force Civil Engineering Center went in place at Tyndall Air Force Base in Florida during 1972, remaining within AFSC until 1977 when the Air Force reassigned the center to the Air Force Engineering and Services Agency.[159] Previously, responsibility for important experimental civil engineering research had existed within the command at Wright-Patterson (from World War II into 1956, and as a field extension of the Directorate of Civil Engineering for Headquarters Air Force), and at Kirtland, first within the Air Force Special Weapons Center and subsequently within the AFWL. From 1951 forward, civil engineering research had concentrated on nuclear hardening issues (see Volume I, Part III).

Consolidation and streamlining of AFSC's organization continued from 1975 into the middle 1980s. In July 1975 the command grouped the Air Force Avionics, Aero-Propulsion, Flight Dynamics and Materials Laboratories at Wright-Patterson as the Air Force Wright Aeronautical Laboratories and further subsumed the Frank J. Seiler Laboratory at the Air Force Academy in Colorado and the European Office for Aerospace Research and Development in London within the Office of Scientific Research at Bolling.[160] (The European Office for Aerospace Research and Development had relocated from Brussels to London in July 1970.[161]) The other laboratories were the Rocket Propulsion Laboratory at Edwards, the Cambridge Research Laboratories at Hanscom, the Human

Resources Laboratory at Brooks, the Weapons Laboratory at Kirtland, and the Civil Engineering Center at Tyndall. AFSC had combined the 13 individually parallel laboratories of mid-1974 into seven a year later. The Armament Laboratory remained subsumed under the Armament Development and Test Center (see Plate 25). The Geophysics Laboratory replaced the Cambridge Research Laboratories at Hanscom in 1976.[162]

More restructuring also occurred during the late 1970s and early 1980s (Plates 26-27). The Space and Missile Test Organization (SAMTO) superceded the Space and Missile Test Center at Vandenberg in 1979 and AFSC split SAMSO as Space Division and the Ballistic Missile Office. Space Division continued to be located at Los Angeles Air Force Station, while the Ballistic Missile Office was physically sited at nearby Norton Air Force Base (where the missiles half of SAMSO had already relocated in mid-1962). Within Space Division were several significant, highly specialized ancillary facilities, including a satellite control installation in Sunnyvale, California, and a test group in Hawaii.[163] The command additionally elevated the former Armament Development and Test Center at Eglin to division level as of the early 1980s. The Armament Division maintained a test group at Holloman, a former R&D installation that continued under TAC. AFSC handled the RADC in this same manner within Electronic Systems Division, with both Hanscom and Rome supporting many off-site research test locations—a situation that had held from the middle 1950s for both. In the middle tier, the Foreign Technology Division kept its division title, but was weighted parallel to SAMTO at Vandenberg and the two remaining test centers of Flight Test at Edwards and the AEDC at Arnold. In April 1982, the Director of Laboratories at Headquarters AFSC at Andrews managed six laboratory clusters, with the Armament Laboratory remaining separate within the Armament Division (see Plate 26). As of October, AFSC tiered not only the AFWL, but also the Geophysics and Rocket Propulsion Laboratories, to Space Division in Los Angeles through an added layer, the Air Force Space Technology Center at Kirtland.

During 1982-1983, AFSC became much simpler in organization, with 12 more or less equally-weighted units reporting to the command headquarters at Andrews Air Force Base (see Plate 27). In many ways, the R&D web of a dozen research and test installations mirrored the first mature structure of the command in late 1953, with some of the original R&D organizational units replaced with later-era missions. In mid-1983, AFSC consisted of Space Division at Los Angeles Air Force Station; the Ballistic Missile Office at Norton; Electronic Systems Division at Hanscom, with the RADC still subsumed within it; the Armament Division at Eglin, still maintaining a test group at Holloman; the Aerospace Medical Division at Brooks, with the Human Resources Laboratory now within its structure; the Aeronautical Systems and Foreign Technology Divisions at Wright-Patterson; the Air Force Contract Management Division and the Air Force Space Technology Center at Kirtland; SAMTO at Vandenberg; the AEDC at Arnold; and, the Air Force Flight Test Center at Edwards.[164]

Over the 30-year period between 1953 and 1983, the 12 research units of ARDC / AFSC had sustained five basic R&D installations—handling intelligence, aeronautical systems, armament, and electronics, sited either at Wright-Patterson or on the East Coast. In 1953, however, three research units had addressed soft-science issues of human psychology, those of the Human Resources Research Center, the Human Resources Research Institute, and the Human Factors Operations Research Laboratories (see Plate 16). Three decades later, a single division addressing hard-science aeromedicine existed, with its Human Resources Laboratory derived from a personnel research laboratory that had originated at Lackland in late 1961. (The early 1950s research units had transferred to a different center at Lackland in 1954 with their functions shifted from ARDC to ATC between 1956 and 1958.)[165] The real change, however, was in the rise of flight test, special weapons, missile, and space R&D units: four had existed in 1953, focused on test centers, while five much larger and more complex units were in place in 1983. Flight test consistently stayed at Edwards, tied to opportunities provided by the isolation and size of its Southern California desert location. Special

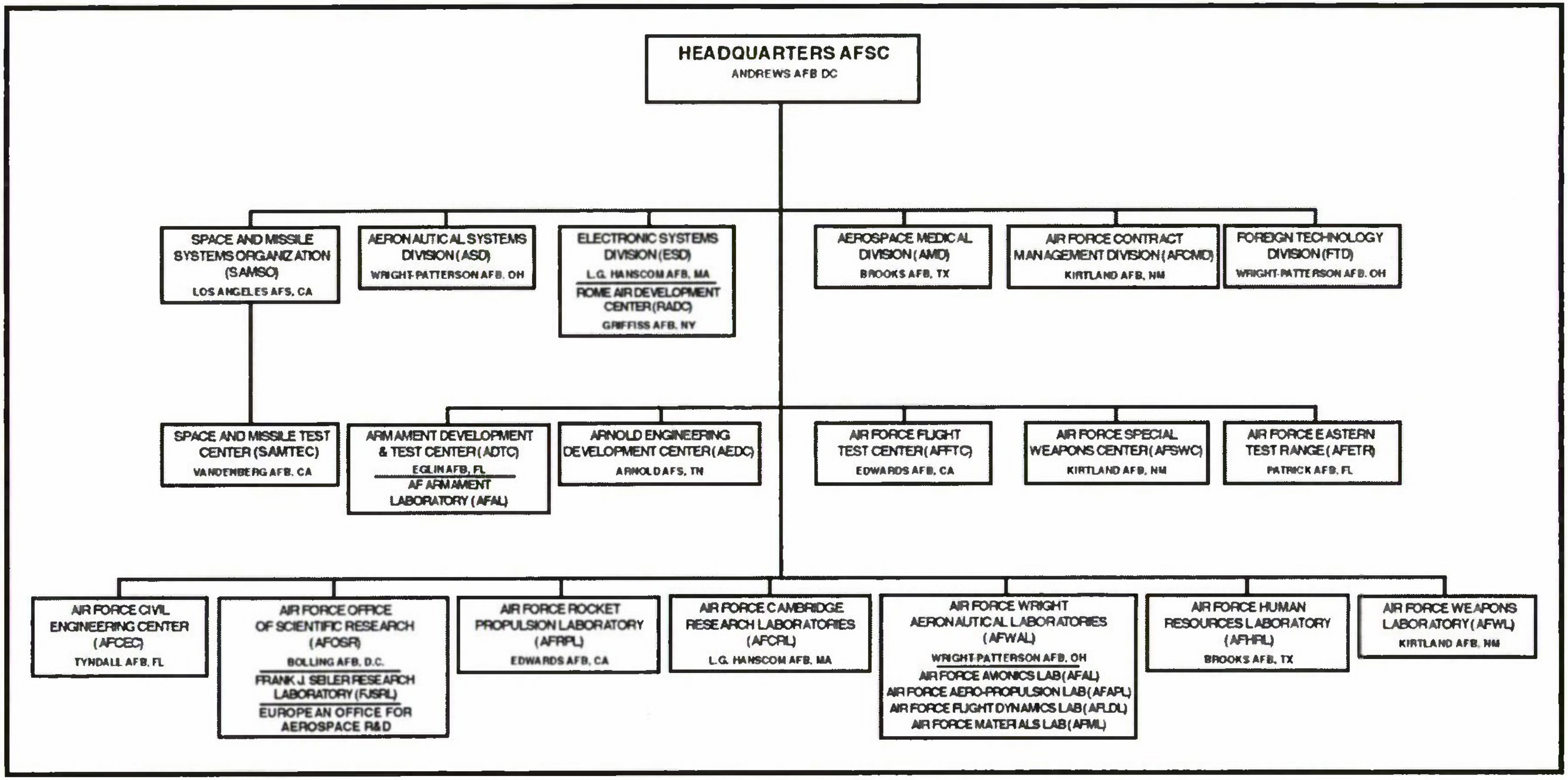

Plate 25: **AFSC Organization Chart, November 1975. Adapted from *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.**

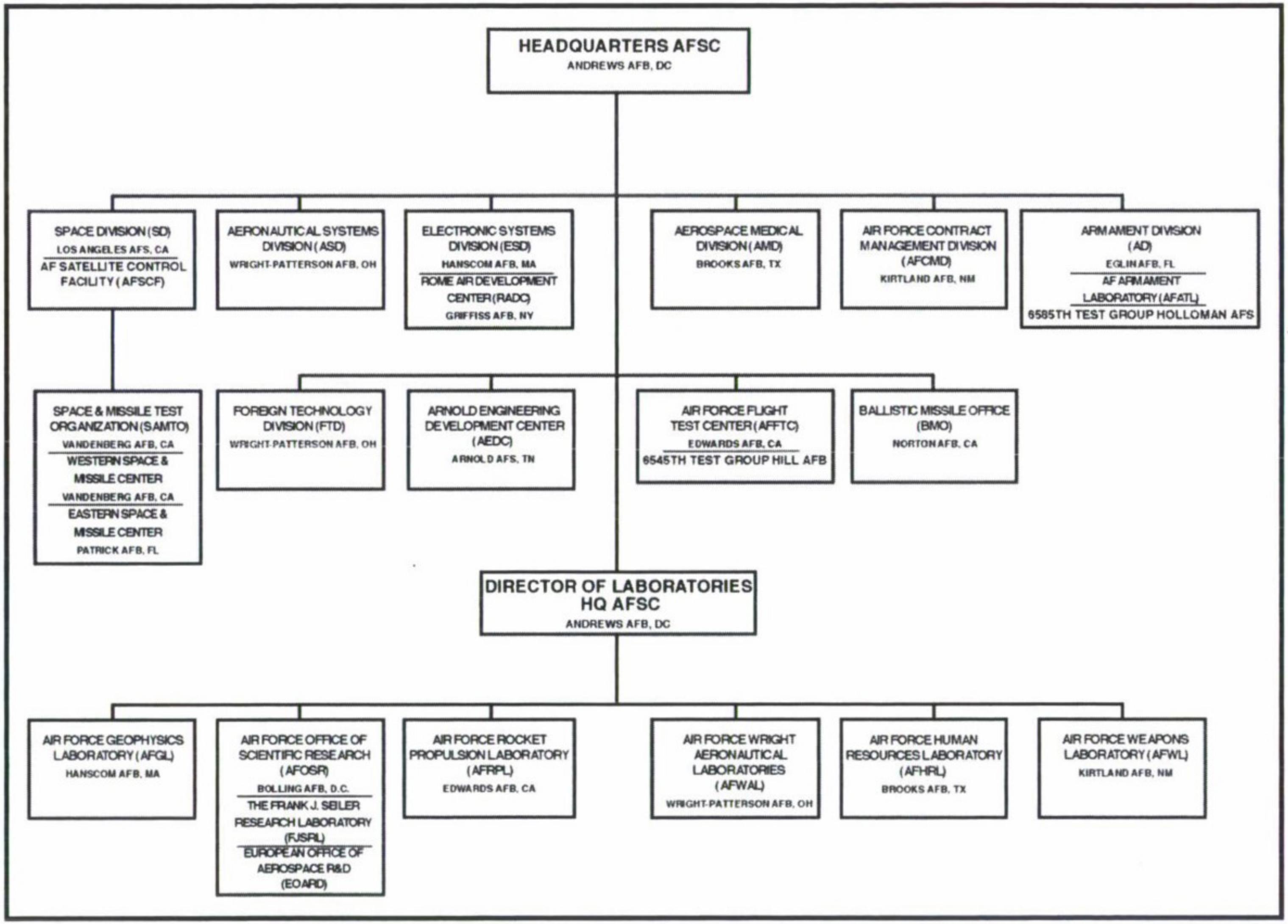

Plate 26: **AFSC Organization Chart, April 1982. Adapted from** ***Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*****, volume 1.**

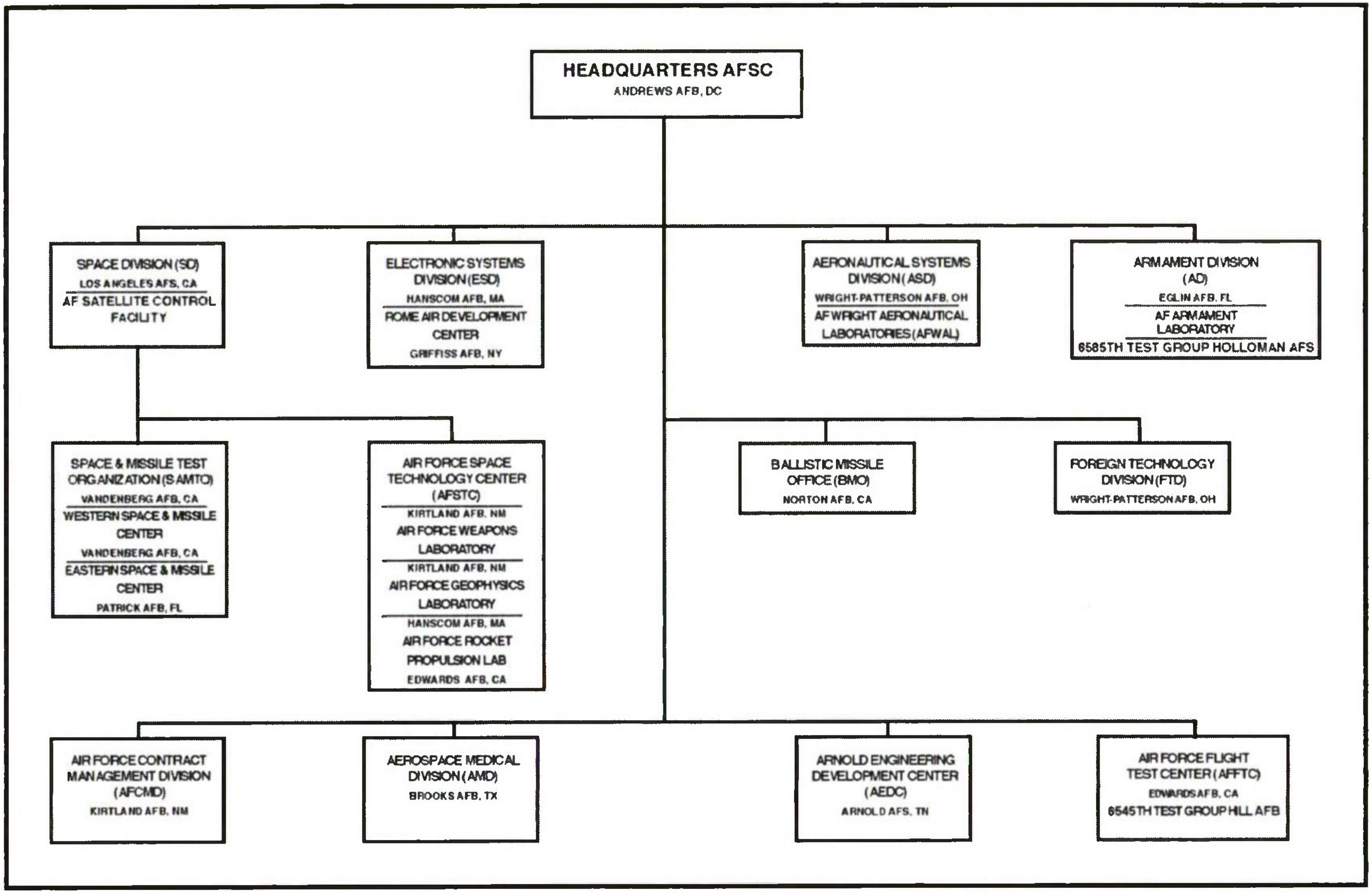

Plate 27: AFSC Organization Chart, July 1983. Adapted from *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*, volume 1.

weapons development involved multiple sites, with testing focused in the Marshall Islands and at the Nevada Test Site. The missile and space R&D missions of the command were those that shifted in physical location over the decades. In the early 1950s, New Mexico was the key site, with efforts additionally going forward in Florida at the Joint Long Range Proving Ground at Patrick from late 1949 forward (renamed the Air Force Missile Test Center in mid-1951 and subsequently the Air Force Eastern Test Range in 1964—physically sited 21 miles north of the installation at Cape Canaveral) and at the Eglin Gulf Test Range (formally designated in the late 1950s, but directly evolved out of a World War II overwater range off Santa Rosa Island). By the 1960s, missile and space testing occurred at Patrick (Canaveral) over the Air Force Eastern Test Range and at Eglin, but with testing also in place at Vandenberg over the Air Force Western Test Range. Missile testing at Holloman disappeared, while range lands west of Hill Air Force Base in Utah supported specialized tests from 1961 forward, culminating in the designation of the Utah Test and Training Range in 1979. Kirtland, too, hosted missile-related testing during the 1960s and 1970s at scattered locations in New Mexico, as well as at the Nevada Test Site and one-time locations in Utah, Colorado and Wyoming. Yet as of 1983, AFSC based almost the entire missile and space R&D mission in Southern California, subordinating the related laboratories at Kirtland and Hanscom. The concentrated focus in Los Angeles as of the early 1980s paralleled that of ARDC at the outset of the 1950s. By 1970, a distinct contract management division also made clear the role of university and industry expertise.[166]

Transition from Air Force Systems Command to Air Force Materiel Command

When the Cold War ended, over the two-year period between the fall of the Berlin Wall in 1989 and formal treaty agreements in 1991, the Air Force began major efforts at command reorganization. As of mid-1992, the Air Force reunited AFSC and AFLC as AFMC—returning to a single command for the R&D and procurement-maintenance / supply missions. AFMC came full circle back to the Air Materiel Command of early 1946, with headquarters returned to its original location at Wright-Patterson. At the time of the transition from AFSC to AFMC, AFSC featured "four major product divisions, each with a subordinate 'super lab,' and three specialized test centers."[167] The 12 R&D units of 1983 were further consolidated into 11. In early 1992, AFSC's divisions were Aeronautical Systems, supported through the Wright Laboratory at Wright-Patterson; Electronic Systems, supported through the Rome Laboratory at Hanscom and Griffiss; Human Systems, supported through the Armstrong Laboratory (of aeromedicine) at Brooks; and, Space Systems at Los Angeles, supported by the Phillips Laboratory at Kirtland. (The Wright Research and Development Center had become the Wright Laboratory; the Air Force Space Technology Center, the Phillips Laboratory; the RADC, the Rome Laboratory; and, facilities at Brooks, the Armstrong Laboratory—with the aerospace medical research laboratory at Wright-Patterson functioning as its detachment.) AFSC also administered the Ballistic Missile Organization (replacing the Ballistic Systems Division of March 1989 – May 1990 that had followed the Ballistic Missile Office), with a sustained location at Norton; test groups at Vandenberg and Patrick; and, the Consolidated Space Test Center at Onizuka Air Force Base in Sunnyvale, California. The Phillips Laboratory, like the Air Force Space Technology Center before it, included multiple sophisticated facilities at Kirtland (through the former AFWL), Hanscom (through the former Geophysics Laboratory), and Edwards (through the former Rocket Propulsion Laboratory). As had been true a decade earlier, the missile-space R&D mission was the largest conglomerate, with its managing unit in Los Angeles elevated from an Air Force Station to an Air Force Base. (With some irony, the hosting public barely acknowledged Los Angeles Air Force Base, due to its lack of aircraft and it highly unusual physical appearance.) The three specialized centers of AFSC were those of the AEDC at Arnold, the Air Force Development Test Center (armament) at Eglin, and the Air Force Flight Test Center at Edwards. These centers had not changed form significantly from the beginning of the Cold War to its end. The Air Force Office of Scientific Research at Bolling also remained affiliated with AFSC in early 1992.[168] As of July 1992, AFMC redesignated its divisions—Aeronautical Systems, Electronic Systems, and Space Systems—as three

centers.[169] Both the ASC and the Electronic Systems Center had previously existed as organizational unit names during the late 1950s under Air Materiel Command. Space and Missile Systems Center combined Space Systems Division and the Ballistic Missile Organization.

Today, the AFMC R&D installations include seven physical locations, essentially reflecting the 1992 configuration but with more reorganization and some installation closure (Norton). Major changes affected through the end of the Cold War included the transfer of the launch operations at Patrick and Vandenberg Air Force Bases from AFSC to Air Force Space Command as of late 1990. Creation of a four-laboratory structure for AFSC had also been a late 1990 change. AFSC deactivated the other major laboratories within the command, assigning their functions to one of the super laboratories. The final major change prior to the shift to reintegration within AFMC was the reassignment of the Foreign Technology Division from AFSC to the Air Force Intelligence Command in October 1991.[170] In 1997, the Phillips Laboratory became the Air Force Research Laboratory (AFRL), adding the Rome Laboratory to the three laboratories previously grouped together since the formation of the Air Force Space Technology Center in the middle 1970s. A recent final change of 2001 was the transfer of Los Angeles Air Force Base (and Space and Missile Systems Center) to Air Force Space Command.

Supply Depots and the Maintenance / Procurement Mission

Under Air Materiel Command: 1946-1961

The depot missions within Air Materiel Command continued to be handled together with R&D during the immediate post-World War II period. Within the T system of organization, Engineering (T-3) and Supply (T-4) served as the umbrella for carrying out the maintenance, supply, and procurement functions—with procurement overlapping confusingly with R&D. Under T-3, the Maintenance Division handled aircraft and miscellaneous maintenance tasks, as well as a publications agenda for printing and reproduction across Air Materiel Command and the wider Army Air Forces. The predominant portion of the materiel mission, however, resided within T-4. In 1946, T-4 included the Supply and Procurement Divisions; the civil engineering function within the Installations Division and the Quartermaster; and, the Air Chemical Office. Of these areas, the ones pertaining to experimental civil engineering and biological-chemical weapons were actually part of the R&D side of the command. Immediately post-war, the Supply Division had planned to streamline its organization, focused on a disposal of wartime stock. Instead, the division deferred immediate action. With opposite needs, the Procurement Division initiated a vast reduction of Air Materiel Command procurement, downsizing its three procurement districts (Eastern, Central, and Western) into a single, centralized office in Dayton. The procurement function also was closely linked to the industrial plants that had supplied the Army Air Forces with its aircraft and aircraft components. As 1946 unfolded, plants in Indianapolis (General Motors); Niagara Falls, New York (Bell Aircraft); Seattle (Boeing Aircraft); Fort Worth (Consolidated Vultee Aircraft); Hagerstown, Maryland (Fairchild Engine and Airplane Corporation); Farmingdale, New York (Republic Aviation); and Wood Ridge, New Jersey (Wright Aeronautical Corporation) hosted a plant representative from the Procurement Division to smooth the transition ahead.[171]

Post-war needs pressed Air Materiel Command in multiple ways. The command faced a challenging responsibility for storing and disposing of large numbers of aircraft. During the first year after the war, seven main fields in the United States served this purpose: Davis-Monthan in Arizona, Garden City in Kansas, Hobbs in New Mexico, Independence in Missouri, Pyote and South Plains in Texas, and Victorville in Southern California.[172] Other installations soon provided the service, including that at Ogden (Hill Air Force Base), with major outdoor storage of mothballed planes. In yet another example, Tinker Air Force Base in Oklahoma City (the Oklahoma City AMA) utilized the World War

II Douglas Aircraft plant in Tulsa as an off-site storage depot for military vehicles, aircraft, and spare parts from about 1945 to 1950.[173] The supply and maintenance tasks assigned to AMAs were also beginning to change as the command slowly reduced the number of areas, ending depot missions at selected installations. Plans of 1945 to achieve seven AMAs, and ultimately two super AMAs in San Antonio and Oklahoma City, were still futuristic. During 1946, Air Materiel Command oversaw 10 primary depots located in an equal number of AMAs, with the formal closure of both Fairfield at Patterson Field in Ohio and Miami in southern Florida (Plate 28). Air Materiel Command transferred the supply and maintenance functions previously assigned to Miami, to the Warner Robins depot at Robins Field in Georgia.[174] The 10 depots were civilian-operated, although during 1946 the command briefly evaluated militarizing one of its depots to sustain an immediate readiness for emergencies. Air Materiel Command first considered militarizing the San Bernardino depot at Norton, shifting its analysis to the Warner Robins depot before abandoning the notion. The command did greatly reduce the number of specialized depots in 1946, from a wartime 35 to a post-war 11.[175]

The AMAs operated under a T system paralleling that at Headquarters Air Materiel Command at Wright and Patterson Fields well into 1947, with much of 1948 occupied with levels of organizational change parallel to those going forward for R&D. As of 1947, the command strongly desired to downplay the supervisory duties of headquarters, seeking to give AMA commanders more voice in their own post-war management. Air Materiel Command tested a less rigid centralized oversight at the Mobile, Oklahoma City, and Sacramento AMAs, beginning in March.[176] By early May 1947 the command had consolidated its 10 AMAs to its goal of seven—achieving the desired streamlining just as the Army Air Forces became the Air Force at mid-year. Redistricting was quite severe, with very large AMAs in the interior of the country and smaller AMAs along the American borders (Plate 29). From east to west, the 1947 AMAs were those of Middletown, Warner Robins, Mobile, San Antonio, Oklahoma City, Ogden, and Sacramento.[177] Although the command planned to remove itself from all of its specialized depots as post-war consolidation proceeded, immediate decisions were to keep those located in Shelby, Ohio (north of Columbus) and Maywood, California (East Los Angeles today) due to their geographic location and warehouse capacity.[178] Air Materiel Command had eliminated the Rome, Spokane, and San Bernardino depots after looking at issues of warehouse space, expansion possibility, existing transportation, regional weather, and local wages for personnel. The command expected that the transfer of stock from these depots to those remaining would require most of 1948.[179] The Air Force eliminated the T system in October 1947, with a major restructuring of its supply procedures during 1948. Air Force equipment was increasingly complex, and national security issues were not those of the pre-World War II years. Air Materiel Command envisioned a future war scenario wherein hours would matter, "without unnecessary loss of time or wasted motion."[180]

Supply and maintenance for the Army Air Forces, and for the early Air Force, relied on a general depot system. In 1948, Air Materiel Command moved ahead with its 1945 plans for two "super depots," refined as a two-zone system that would continue to use the existing seven depots in the continental United States. The older general depot system operated with each depot providing complete supply and maintenance support for all Air Force installations within the boundaries of its geographic AMA.

> Each depot stocked, for the most part, the same supplies. The facilities, machine tools, and the like were duplicated in each area depot and none was fully utilized. The control of stocks was quite a problem in the depot system. It was also difficult to give an area depot a long-range maintenance workload, mostly because of lack of availability of reparables at any one depot.[181]

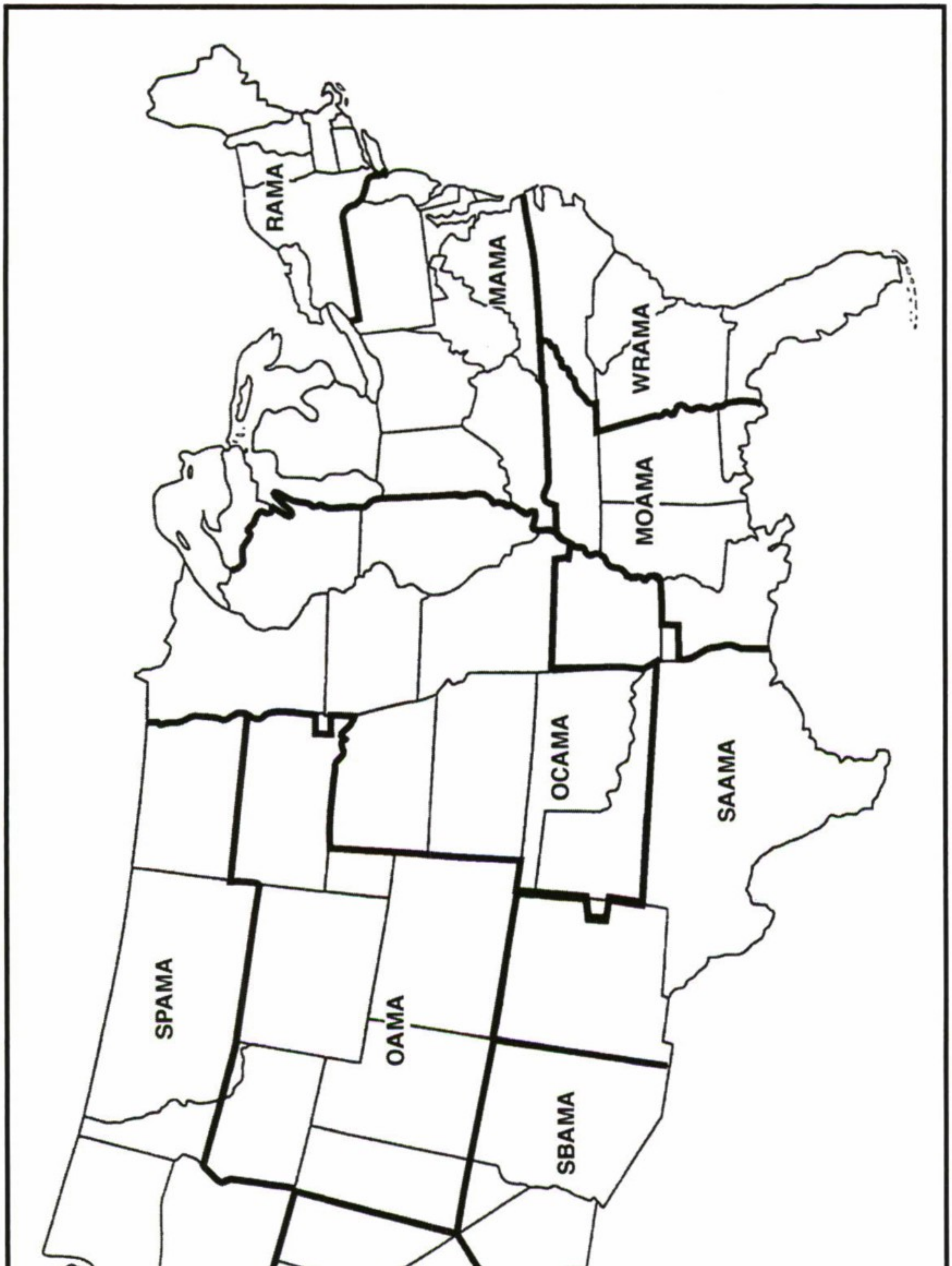

Plate 28: Air Materiel Command, Air Materiel Areas, 15 September 1946. Adapted from *History of the Air Materiel Command 1946*, volume 1.

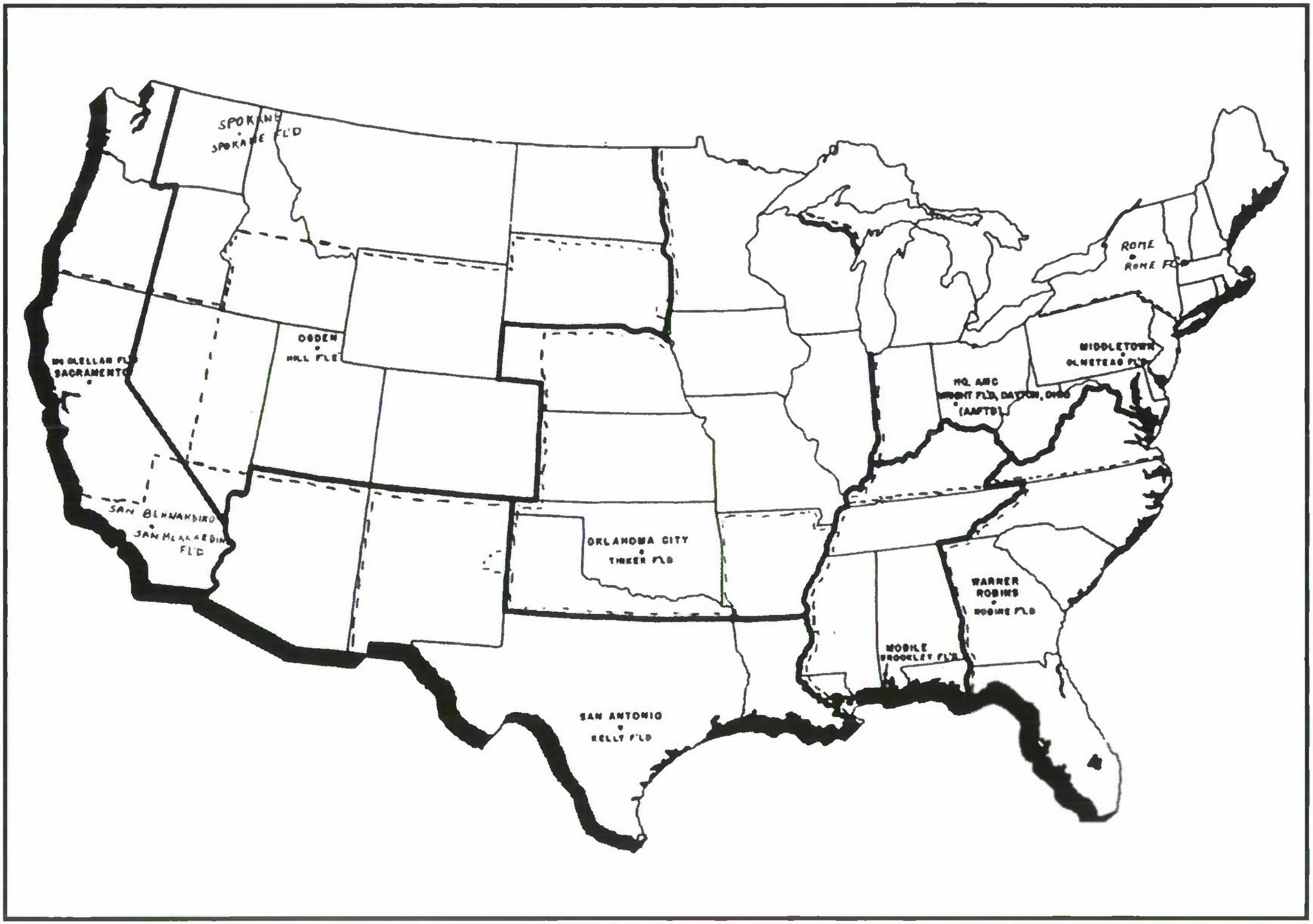

Plate 29: Air Materiel Command, Air Materiel Areas, 15 May 1947. Dotted lines indicate AMA boundaries of 1946. With the redistricting of 1947, Air Materiel Command eliminated the depots at Spokane, San Bernardino, and Rome. In *History of the Air Materiel Command 1947*, volume 2.

The two-zone supply distribution system of April 1948 was the idea of the Director of Supply and Maintenance for Air Materiel Command, Major General Charles B. Stone, III. Alternate names for the system were the Bi-Zonal Plan and the Stone Zone Plan. The Mississippi River, continued as a dividing line along the eastern boundaries of Illinois and Wisconsin, would separate the continental United States into two unequal halves, with the West and its fewer installations a much larger physical area. Both zones would be fully stocked with materiel, but within each zone Air Materiel Command would stock only certain supplies at each depot. The east zone would support Air Force bases east of the Mississippi, and those in Europe, Northeast Air Command, North Africa, and the Caribbean. Similarly, the west zone would support its geographic installations, and bases in Alaska, Hawaii, and Asia. For service testing, Air Material Command demarcated the two zones along the Mississippi River, splitting the Oklahoma City AMA *temporarily* into two parts (Plate 30). The command service-tested the two-zone system at the Middletown AMA during the last six months of 1948. (It is assumed that Air Materiel Command planned to stock the Middletown AMA and the Oklahoma City AMA with the same supplies, with Middletown operating within the east zone and Oklahoma City within the west zone. For the service test, Middletown could then supply bases in both the east and west zones, acting on behalf of itself and Oklahoma City.) Each of the major Air Force commands, SAC, ADC, and TAC, as well as Air Materiel Command and its AMAs, all reported that the reorganization was more efficient than the general depot system. The Air Force also concluded that a two-zone supply system was less vulnerable to enemy attack, and that in a situation of war the two-zone system could become a three- or four-zone system by adding specialized supply depots sited in industrial centers. Air Materiel Command expanded the two-zone concept throughout its AMAs as of January-March 1949, with a full transition to the new system anticipated in 1951. The final demarcation no longer cut through the Oklahoma AMA, but followed its eastern edge (and thus, only partially paralleled the Mississippi River) (Plate 31).[182]

As of 1948 the command also applied modern business and manufacturing practices to supply warehousing, with a focus on automation. The War Department had achieved substantial standardization for property accounting and stock reports during World War II, but had relied upon hand-posted index cards, primitive calculating machines, and marginally efficient equipment for preparing the data needed to keep track of warehoused stock. The system did not work well for a large-scale operation, and certainly did not accommodate tracking of supplies on an international basis. Emergency stock reporting, or expansion of warehoused items, was also not very successful. During late 1948 and early 1949, the Air Force directed Air Materiel Command to adopt the mechanized procedures of the Army. Service testing began at the Mobile AMA. Air Materiel Command code-named the mechanization of its stock control system Project WISE (World-Wide Installation of Supply Economy).[183]

As 1949 opened, Air Materiel Command managed its supply and maintenance missions at seven major depots, five specialized depots, and two aircraft storage fields, through the Directorate of Supply and Maintenance—one of three directorates structuring the command.[184] Air Materiel Command had hoped to reduce its specialized depots to those at Shelby, Ohio, and Maywood (Los Angeles), and after an interim period to none (down from the 35 of World War II) (see Plate 30). Instead, five of these depots remained active: the 822nd at Maywood, California; the 830th at Memphis, Tennessee; the 831st at Shelby, Ohio; the 832nd at Topeka, Kansas; and, the 862nd at Dayton.[185] (The specialized depots in Shelby and Dayton were alternately known as Wilkins and Gentile Depots.) By FY 1950, Air Materiel Command realized that the reduction from 12 World War II AMAs to seven had been too severe. Sacramento, for example, faced overloaded storage and maintenance issues, serving Alaska and the Pacific in addition to its continental AMA. In order to relieve conditions at the Sacramento AMA, the command reactivated the San Bernardino AMA as of 30 November and revised area boundaries accordingly.[186] As of late 1949, about one-third of the AMAs had achieved a full change-over to the two-zone system of stock storage and organization. Air

Plate 30: Two-Zone System Supply and Maintenance Locations (Service Test), June-December 1948. Adapted from *History of the Air Materiel Command 1948*.

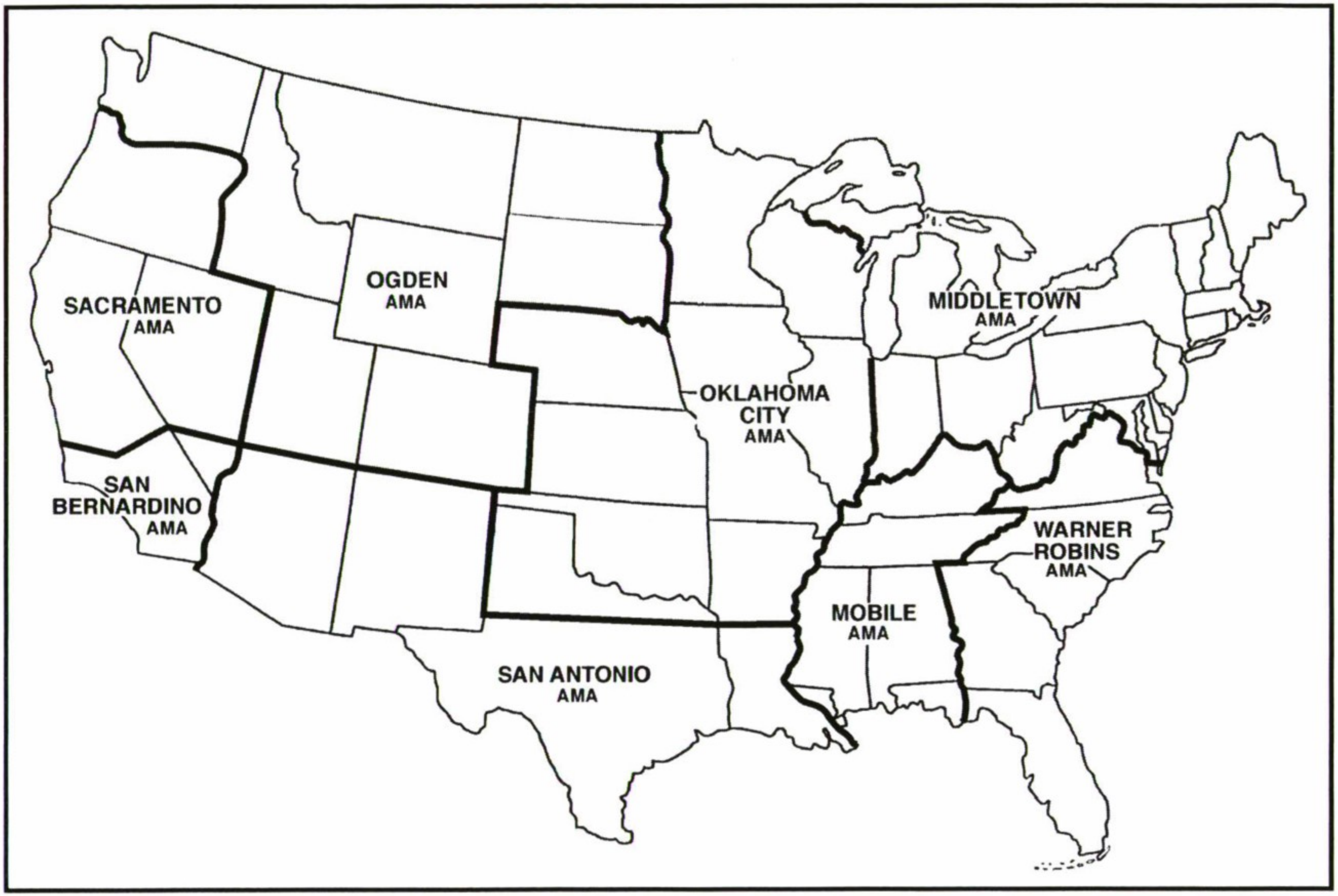

Plate 31: Air Materiel Command, Air Materiel Areas, 1 December 1949. Adapted from *History of the Air Materiel Command 1 January – 30 June 1949.*

Materiel Command planned to incorporate its sustained specialized depots within the two-zone system as well, further alleviating overall storage problems and compensating for a reduction that had been overzealous. The zone east of the Mississippi included three AMA depots: Middletown, Mobile, and Warner Robins, supplemented through the three specialized depots in Dayton and Shelby, Ohio, and in Tennessee. The western zone, in contrast, operated five AMA depots: Ogden, Oklahoma City, Sacramento, San Bernardino, and San Antonio, with augmentation through the two specialized depots in Kansas and Southern California[187] (see Plate 31).

In January 1950, Air Materiel Command retained the missions of supply, maintenance, and procurement, with the R&D function segregated as ARDC. Eight established AMAs, with both primary and specialized depots, handled supply and maintenance. The depots also began to seriously gear up for the Korean War, retrofitting and modifying aircraft for deployment to the Far East in partnership with selected Air Force industrial plants. With the formal outbreak of war in late June 1950, Air Materiel Command accelerated the depot modification programs. SAC sent its B-29 bombers to the depot at Hill Air Force Base (the Ogden AMA) for reconditioning. TAC required modification of 223 B-26s for Far East Command, a task that included relocating electronic equipment and installing new features on the aircraft. The B-26 effort was the responsibility of the depot at McClellan Air Force Base, within the Sacramento AMA. Aircraft modification projects not related to the Korean War effort also went forward at a faster pace as of this date. Sacramento handled Project Reliable to install accurate radar, navigation, and bombing systems in multiple aircraft, concentrating initially on changes to the B-50. Simultaneously, the depot at Tinker Air Force Base (the Oklahoma City AMA) installed parallel radar, navigation, and bombing systems on 10 B-36s, as well as working on a prototype C-119. The depots at Robins Air Force Base south of Macon, Georgia (the Warner Robins AMA), and at Kelly Air Force Base (the San Antonio AMA), prepared 72 B-29s for shipment to Great Britain, with the depot at Brookley Air Force Base in Alabama (the Mobile AMA) modifying 100 B-25s for shipment to Canada.[188]

An important new storage and supply mission also arrived for Air Materiel Command by 1950: special weapons support, first defined as the triumvirate of atomic, biological, and chemical (ABC) weapons. After World War II, the Army Chemical Corps had adapted bombs and guided missiles for biological and chemical agents, jointly testing these new weapons with the Army Air Forces. Installations selected for component testing of these weapons systems were initially Muroc (Edwards) and Eglin Fields, with the former offering dry lake beds for drop testing and the latter providing ranges for test scenarios. During the late 1940s the specialized weapons program, shared by the Air Force and the Army, had continued to advance and included not only the ARDC installations of Edwards and Eglin Air Force Bases, but also Holloman and Kirtland. (The Army's effort concentrated in the chemical and radiological laboratories at the Army Chemical Center at the Edgewood Arsenal and at the biological laboratories at Camp Detrick [Fort Detrick as of 1953], both in Maryland.) Wright-Patterson coordinated the ARDC contribution to biological-chemical weapons testing (see Volume I, Part III).[189] The situation for nuclear weapons, first atomic and then thermonuclear, was even more complex. For this program, Headquarters Air Force set up an Air Force Office of Atomic Energy (AFOAT), and within it a biological-chemical division. Air Materiel Command's role in an unfolding atomic weapons program rapidly increased after the detonation of an atomic device in the Soviet Union during 1949. As of the early 1950s, devising appropriate support became paramount within the command. The supply and maintenance mission expanded to include selected logistical needs of experimental atomic tests in the Marshall Islands and later at the Nevada Test Site, as well as "adapting aircraft, equipment, and supplies to the requirements of atomic warfare; creating a special weapons logistics organization, including a depot structure; and training personnel for the special requirements of logistics support."[190]

Air Materiel Command also was involved with the cutting-edge engineering required for the Air Force storage depots that would hold nuclear materiel. The command worked very closely with the

Armed Forces Special Weapons Project (AFSWP) at Sandia Base in Albuquerque, and with AFOAT in Washington, D.C. The Sandia Corporation derived from the Z Division of the Sandia Laboratory (named for physicist Jerrold R. Zacharias of MIT's Radiation Laboratory of World War II), which in turn was closely affiliated with nuclear work at Los Alamos. The Z Division evolved as Sandia Base, moving from Los Alamos to a site neighboring Kirtland. As of 1947, Sandia Base was responsible for the engineering details and production sites of ready-made atomic weapons, also responsible for their military-assembly, testing, and maintenance. Sandia began training Air Materiel Command personnel to carry out the required functions of the Air Force's nuclear depots in the Operational Storage Site program and at Department of Defense stockpile locations where the Air Force had management responsibility (in the National Storage Site program) (10 of the 13 total sites in the continental United States). The War Department had hired the architectural-engineering firm Black & Veatch of Kansas City to design and engineer the complement of structures needed for the depots. These enclaves were soon known as Q Areas due to the associated Q security clearance required by the AEC (and later by the Department of Energy [DOE]).[191]

In June 1946, the War Department had sole-sourced Black & Veatch the design and engineering of nearly all of the weapons-related R&D facilities at Los Alamos, including site development, utilities, and atomic weapons storage—as well as most of the housing, special service buildings, technical laboratories, and process buildings. E.B. Black and Ray E. Lawrence, respectively partner and assistant civil engineer within Black & Veatch, had both served within the Army's Quartermaster Corps during World War II in Washington, D.C. (with Black also working within the Quartermaster Corps during World War I). After the war the Chief of Engineers of the Corps had invited Black & Veatch to handle the Los Alamos and special weapons storage assignment. Black & Veatch continued to design and engineer all of the structures for early nuclear weapons storage. As Design Group 115 within Black & Veatch, the firm's AEC team included 175 personnel, with 85 engineers in residence at Los Alamos for a two- to five-year period. The remainder of Design Group 115 operated out of the former Pratt & Whitney aircraft plant in Kansas City, a segregated location from that of the main Black & Veatch offices in town. For a complementary project, Design Group 470 of Black & Veatch undertook the simultaneous AEC conversion of the Army ammunition plant at Burlington, Iowa, for nuclear weapons work.[192]

Sandia supervised construction of the first nuclear materiel storage areas, with Sites A-D (Able, Baker, Charlie, and Dog) built between November 1946 and 1951 (and including Manzano Base at Kirtland). These first four specialized depots were main stockpile sites (of six such sites total), with the earliest literally built inside existing mountains. Underground igloos and subterranean plants characterized Sites A-C, with Site Able (Manzano Base) under construction by 1947 and minimally operational at the end of 1949. Sites Baker and Charlie, the second and third stockpile facilities underway, came on line before Manzano Base—at Killeen Base neighboring Fort Hood in Texas (supported by facilities at adjacent Gray Air Force Base) and at Clarksville Base neighboring Fort Campbell on the Kentucky and Tennessee border (supported by adjacent Campbell Air Force Base). These three stockpile facilities functioned as storage sites for the tri-services, the Air Force, Army, and Navy. Site Dog was the main stockpile location of Bossier Base, neighboring Barksdale Air Force Base in Louisiana. Next, Sandia moved to smaller alert depots (Operational Storage Sites). Sites E-I bordered the five SAC bases of Limestone (Loring) in Maine, Rapid City (Ellsworth) in South Dakota, Fairchild in Washington (the Spokane AMA from 1942 to mid-1947, and again from 1952 to mid-decade), Travis in California, and Westover in Massachusetts.[193] By mid-November 1950, Headquarters Air Force assigned Air Materiel Command management of Manzano Base. Simultaneously, Air Materiel Command established the Kirtland Air Force Specialized Depot (the 2837th Specialized Depot)—further assigning its management to the San Antonio AMA at Kelly Air Force Base.[194] By March 1951, Headquarters Air Materiel Command at Wright-Patterson issued an organizational directive for "AF Specialized Depots." The mission of these depots was to "[p]rovide

concentrated storage, distribution, and maintenance of special weapons, weapon components, kits, kit components, and training equipment."[195] The next month, Air Materiel Command was not only supervising the preliminary planning and construction efforts for Sites E-I, but was also managing the Black & Veatch contracts for nuclear materiel storage depots overseas as directed by Headquarters Air Force. The Research and Development Branch of Air Materiel Command's Procurement Division handled these supervisory efforts, an assignment which blurred the lines between critical civil engineering R&D (see Volume I, Part III) and the supply-maintenance mission.[196]

To manage the Air Force specialized nuclear materiel depots, Air Materiel Command established an Aviation Depot Wing at Wright-Patterson (the 3079th), and Aviation Depot Groups (subsequently, Squadrons) at the Operational Storage Sites E-I. The AFSWP and Sandia trained Air Force personnel during early 1951 to carry out management of the depots. In May of that year, the AFSWP instructed about 250 Air Materiel Command personnel in management tasks, planning to train Air Force men "until such time as the Air Materiel Command was capable of carrying out the depot functions."[197] The construction program continued into about 1957. Following upon Sites A-I were those of J, the Skiffes Creek Annex of the Naval Weapons Station at Yorktown, Virginia; K, Medina Base adjacent to Kelly and Lackland; L, Lake Mead Base adjacent to Nellis Air Force Base in Nevada (also known as Area II); and Y, the North Depot Activity at the Seneca Army Depot in New York.[198] Air Materiel Command also contracted for about 13 Operational Storage Sites for nuclear materiel overseas, beginning in August 1950. Air Materiel Command integrated planning for these depots with SAC. Locations included England (five depots), Morocco (three), Spain (two), Canada (one), Guam (one), and Japan (one). Management of the overseas depots was particularly complex in its Air Force lineage, with most (if not all) initiated as Aviation Field Depot Squadrons at Kirtland.[199] After a period of six months to a year, numbered Aviation Field Depot Squadrons transitioned into more permanent units under SAC. For the program in the continental United States, Air Materiel Command managed the special depots from the transition period within the AFSWP and Sandia at the outset of the 1950s, until 1962 when control passed fully to SAC. As of 1962, the Air Materiel Command depots became Air Force Stations, a change occurring just after Air Materiel Command reorganized to become AFLC.[200] Air Materiel Command assigned atomic weapons and its ancillary components (such as detonator pits and booster capsules) the special property class designation of 09-D. The command organized the entire depot system by numeric property class. The 09-D class for nuclear materiel fit into a larger scheme that ranged from aircraft spares and engine parts, to ground communication and printing equipment. After conferring with SAC, TAC, and AFOAT, Air Materiel Command also added a section to the general *Air Force Supply Manual* as of late June 1951 that covered the "requisitioning, issue, storage, stockbalance reporting, and related procedures" for nuclear materiel.[201]

Warehousing and depot supply logistics of the Cold War era differed substantially from those of World War II. Air Materiel Command closely addressed the physical infrastructure of warehousing, contracting at least three times during the 1950s for innovative warehouses at its depots. Emphasis was not only on size and efficiency of construction, but also on cost-effective variations in materials and unit structure, applied at one depot and improved at another. Warehouses built for Air Materiel Command appeared in the American civil engineering journals *Engineering News-Record* and *Civil Engineering*, with the professional community publishing critiques and analyses of strides forward, as well as set-backs. The command further adopted modern business practices to make its depot operations rival those of large storage facilities in private industry. As the 1950s unfolded, the Air Force made General Edwin W. Rawlings Commander for Air Materiel Command at Wright-Patterson. General Rawlings had managed budgets within the Materiel Division at the base in the middle 1930s. The Air Corps had sent him, along with one other individual, to the Business School at Harvard University to get an Masters in Business Administration (MBA) during 1937-1939. General Rawlings, as Commander of Air Materiel Command from 1951-1959, applied the skills of the MBA to automate and streamline the business of warehousing.[202]

At the beginning of 1952, Air Materiel Command's most pressing general problem at the depots was lack of sufficient warehousing. Again, the command reopened a depot that it had closed in mid-1947—in this instance that of Spokane at Fairchild Air Force Base (as of April 1952).[203] The Spokane depot functioned parallel to the special storage depots, such as the Wilkins Air Force Specialized Depot in Shelby, Ohio, and did not return to Air Materiel Command as a primary aircraft maintenance and repair facility. Fairchild, hosting the depot, was in transition to SAC, with an immediately neighboring Q Area soon to be under construction for storage of nuclear materiel under Air Materiel Command. Warehousing efficiency under General Rawlings began with approval from the Department of Defense for 5,696,000 square feet of new warehouse construction during FY 1952. The Air Force authorized the square footage as well, with the projected space allocated to both primary depots (for AMAs) and key special storage depots (distinct from those for nuclear materiel) within Air Materiel Command. Planned as of late 1951 were new warehouses for nine depots. The first of these scheduled, at Griffiss Air Force Base, was also a reinstated depot for the command. As was the case for Spokane, the Rome, New York, installation came back on line as a special depot rather than as a primary depot for an AMA, and was, thus, smaller than the norm. (The Griffiss depot fell within the Middletown, Pennsylvania, AMA in the early 1950s.) Air Materiel Command planned a warehouse of 160,000 square feet for Rome. Additionally listed were warehouses of 400,000 square feet at Brookley in Mobile; 400,000 square feet at Tinker in Oklahoma City; 216,000 square feet at Norton in San Bernardino (again smaller than average, as the command had reinstated the San Bernardino AMA only to alleviate the overload for Sacramento to the north); 1,200,000 square feet at Robins in Georgia; 40,000 square feet at the Topeka Air Force Depot (a very small special depot); 480,000 square feet at Kelly in San Antonio; 800,000 square feet at the Wilkins Air Force Specialized Depot in Shelby (an unusually large special depot also known as the Wilkins Air Force Depot and the Shelby Air Force Depot); 480,000 square feet at Gentile Air Force Depot in Dayton (again, very large for a special depot); and, 1,520,000 square feet at McClellan in Sacramento.[204]

Air Materiel Command anticipated that the full complement of warehouses would be available in 1954. The command evaluated its storage space as 37,653,000 square feet at the end of April 1953, with 9,100,000 square feet of materiel temporarily stored outside. The materiel stored in the open was unauthorized for such storage and was deteriorating. Air Materiel Command estimated that its deficit of warehousing would reach 20,000,000 square feet by mid-1955. Although planned construction for warehouses (in progress during 1951-1952) made these conditions somewhat better, the situation was nonetheless worsening more quickly than it was improving. While physical construction went forward, the command focused on attaining industry benchmarks for what it termed "standardization action" and "interchangeability." Air Materiel Command strove for a "common supply language," as well as for much closer control over manufacturing methods and tooling. The command worked toward removing duplication of effort and expense, partially in reaction to a wider Department of Defense and Congressional mandate set forth in the Defense Cataloging and Standardization Act.[205]

General Rawlings continued to insist on decentralization within Air Materiel Command, with headquarters at Wright-Patterson operating only as a management organization and with the command's field organizations responsible for their own affairs. As of July 1953, Air Materiel Command managed six air procurement districts (see below) and maintained eight AMAs. Air Materiel Command depots sustained local, zonal, and international materiel responsibilities. The system in the continental United States continued to feature two zones dividing East and West. The smaller special depots became Air Force Stations, increasing by one. These installations were those of Cheli (Maywood [East Los Angeles]) in California; Gadsden in Alabama; Gentile (Dayton) and Wilkins (Shelby) in Ohio; Mallory in Memphis; Rome in New York; and, Topeka in Kansas. Finally, Air Materiel Command managed two transportation control depots—very large operations on the East and West Coasts that handled materiel for shipment overseas. The transportation control depot for

the East, in Newark, New Jersey, first reported to the Middletown AMA at Olmsted, although the command reassigned it to its headquarters at Wright-Patterson at the close of 1953. The transportation control depot for the West initially functioned in Stockton, California, followed by a relocation to Alameda in the San Francisco Bay Area.[206]

As of spring 1953, Air Force general logistics overseas had also begun evolving in more complicated directions. In Europe, the United States Air Forces in Europe (USAFE) fully controlled logistics until this date. USAFE worked closely with the North Atlantic Treaty Organization (NATO) however, and as Spain, Morocco, and the Azores became important new locations for an Air Force presence, the handling of Air Force depots overseas required reevaluation. Spain was not a NATO country. To accommodate this situation, the Air Force assigned an AMA for Spain to Air Materiel Command. The AMA for Spain was the first AMA for the command in Europe. As of late 1955, Air Materiel Command took over the Air Materiel Force, Pacific Area, headquartered in Japan. The action resulted in the acquisition of two more overseas AMAs, the Northern AMA managed from Tachikawa Air Base in Japan and the Southern AMA managed from Clark Air Base in the Philippines. In January 1956, the command similarly assumed jurisdiction for the logistics missions of the Air Materiel Force, European Area. Air Materiel Command's expansion in Europe included three major AMAs, the Northern AMA in England; the Central AMA in France; and, the Southern AMA in French Morocco, with large depots at Burtonwood, Chateauroux and Nouasseur Air Bases. Five additional air depots supported the European operations of the command. (With these changes, Air Materiel Command integrated the AMA for Spain under the Air Materiel Force, European Area.) By mid-1958, Air Materiel Command's AMA and depot program overseas reversed its expansion, with depots phased out in Europe and the Pacific over the next four years. Air procurement regions replaced AMAs, with depot stock and workloads transferred to AMAs in the United States. For a brief period, the Middletown and Sacramento AMAs managed the overseas procurement regions, but by early 1963 this responsibility shifted to Headquarters AFLC at Wright-Patterson.[207]

For the warehouse expansion of 1951-1957, Air Materiel Command turned to L.P. Kooken, an architectural-engineering firm in Baltimore. With Headquarters ARDC established in Baltimore simultaneously, Air Materiel Command may have favored the firm due to its presence in the same city. L.P. Kooken had also recently established itself as a leader in the design and engineering of very large structures. In 1950, the engineering community had recognized L.P. Kooken for its successful design of a reinforced concrete stadium for the Baltimore Orioles. The Orioles stadium had just opened that year. At the outset of 1951, L.P. Kooken also had handled the design and engineering for the armament hangar and laboratory at Eglin (under Air Materiel Command).[208] The first iteration of formal drawings, for what came to be referenced as the "Special A.M.C. Warehouse," is dated mid-April 1951, and is likely linked to regional prototypical efforts at Tinker by the Oklahoma City architectural-engineering firm Hudgins, Thompson & Ball (see Volume II, Chapter 12). By spring 1952, a second version of the warehouse existed, with fully 62 drawings completed. A third upgrading of the warehouse occurred in late 1954, with changes continuing into 1957. The earliest L.P. Kooken rendition featured a rigid-frame reinforced concrete structure, cast in place with continuous girders. Efficiency and automation of the construction process, as well as the adaptability of the structure to modular extensions in size, were hallmarks of the warehouse. Interpreted another way, the Special AMC Warehouse directly reflected the business philosophy of Air Materiel Command's leader, General Rawlings. The 160,000 square-foot warehouse at Griffiss in New York was a mathematically smaller structure than the 1,500,000 square-foot set of warehouses at McClellan in California, but the warehouses at both locations were essentially identical in framing and plan.[209]

Before Air Materiel Command completed the building program for the Special AMC Warehouse, both square footage, as well as locations and numbers of warehouses, increased dramatically from those of 1951-1952. Locations for the storage facilities doubled from 10 to 20,[210] with the predicted

(but not yet fully confirmed) sites those of the eight primary AMA depots (Middletown, Mobile, Ogden, Oklahoma City, Sacramento, San Antonio, San Bernardino, and Warner Robins); and, the 10 Air Force Depots of Cheli (Maywood), Gadsden, Gentile, Kansas City, Mallory, Rome (reinstated as an AMA depot in late 1958), Slack in Louisiana, Spokane, Topeka, and Wilkins. The two transportation control depots for Atlantic and Pacific overseas materiel are of unidentified physical location, but were most likely co-sited with the AMA depots at Robins in Georgia and McClellan in California. Robins and McClellan each sponsored a pair of very large Special AMC Warehouses, atypical of any other sites.[211] As first built, the Special AMC Warehouse was sometimes more conservative in its structural engineering technology than as of about 1954-1955. (A situation certainly true for the prototypical warehouse at Tinker by Hudgins, Thompson & Ball, which was steel-frame, featured concrete block walls, and was not of standardized modular width.) While L.P. Kooken's rigid-frame reinforced concrete system was truly innovative for 1951-1952, the system was more traditional when combined with hollow tile or concrete block walls. A 400,000 square-foot warehouse at Tinker was under construction as of January 1953—the second of three Special AMC Warehouses on base—and is an excellent example of the conservative version of the warehouse (see Volume II, Plate 176).[212] By mid-decade, two different rigid concrete framing systems were in use (A and B), with three variations in wall paneling (masonry, poured-in-place, and precast) and two variations of roof slab (precast plank and thin-shell, precast, ribbed-slab) (Plates 32-33).[213]

During the early 1950s engineers worldwide were discussing the promising future for rigid-frame, precast, thin-shell construction. Precast, thin-shell structures relied on "framing elements consisting of a thin slab and stiffening ribs, arranged to form miniature systems of framing of any desired shape."[214] The Chief Designing Engineer of the Navy's Bureau of Yards and Docks, the internationally prominent Armenian engineer Arsham Amirikian, described the innovative system in *Civil Engineering* in August 1953, noting that then-current Navy warehouse projects used over 7,000,000 square feet of thin-shell reinforced concrete wall and roof panels in single-story construction.[215] The Navy had experimented with prefabricated wall slabs for dormitories at its Great Lakes training station in Upton, Illinois, in 1951.[216] The Air Force had also moved in this direction as of 1952. For Lockbourne Air Force Base in Columbus, Ohio, 13 dormitories incorporated a steel frame system with reinforced concrete floor and roof slabs, in a variation from standard structures that relied on the Youtz-Slick Lift Slab Method.[217] In another governmental arena, the International Airport Industrial District at Los Angeles simultaneously developed a 95-acre site relying on warehouses of precast, tilt-up construction.[218]

The Air Force explored wider applications of rigid-frame, precast, thin-shell construction as of mid-1953. Air Materiel Command had proven that the technology was cost-effective and efficient through the Special AMC Warehouse program, while the larger events of the Cold War demanded significant expansion of airfield locations. The technology was especially appropriate overseas, where materials often required shipping to site and use of unskilled labor was essential. Also important was the total amount of construction items needed, the interchangeability of building components, the speed of buildout, and the bottom-line cost. During the summer of 1953, the Air Force directed the Atlantic District of the Army Corps of Engineers to hire Roberts & Schaefer to prepare an alternate design employing precast concrete for selected conventional steel and wood buildings typical of Air Force installations. The specific project was at Lajes Field in the Azores.[219] David P. Billington, mentored by Anton Tedesko, served as the Roberts & Schaefer project engineer. The Lajes project featured precast, reinforced concrete rigid frames. Other elements were the concrete precast floor and roof slabs, with five-inch thick concrete precast wall panels tilted up into place. The use of precast thin-shell concrete construction for Lajes received international engineering attention, and saved the Air Force 21 percent in building costs over traditional methods, again evoking goals and lessons learned from Air Materiel Command.[220] In July 1954, more than 200 architects and engineers convened at MIT to describe their experiences with thin-shell concrete construction, including a number of prominent engineers from outside the United States.[221]

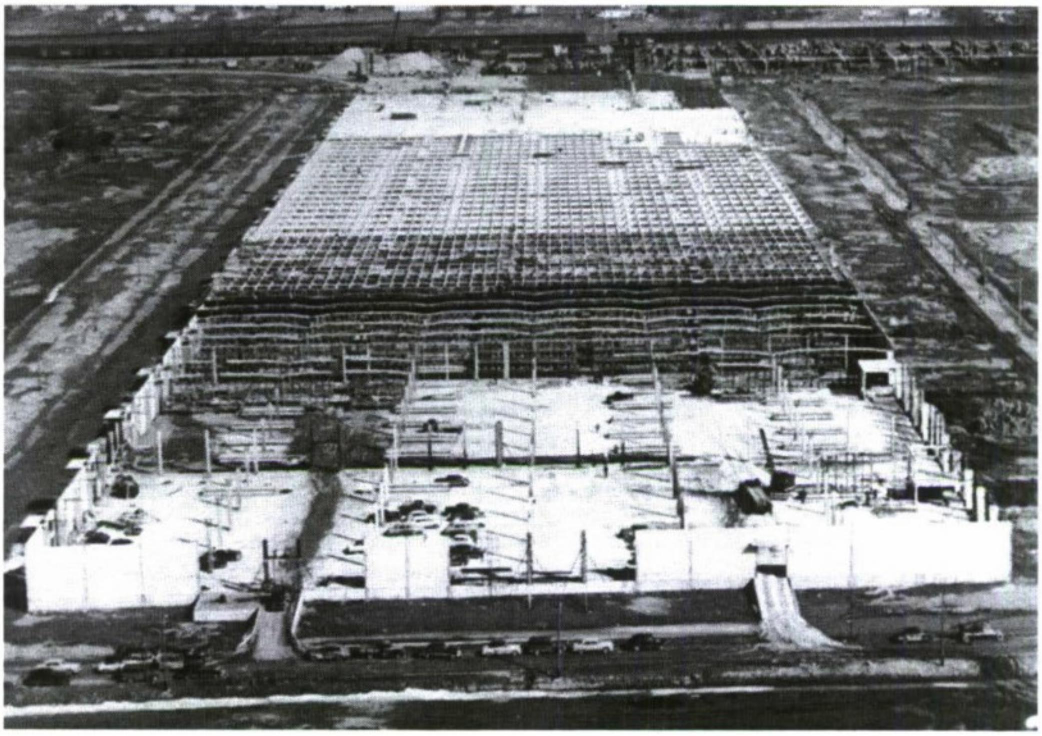

Plate 32: L.P. Kooken. Special AMC Warehouse, Shelby Air Force Depot. Under construction 12 August 1954. In *History of Shelby Air Force Depot 1 July 1954 – 30 June 1955*, volume 1.

Plate 33: L.P. Kooken. Special AMC Warehouse, Shelby Air Force Depot. As completed 5 November 1954. In *History of Shelby Air Force Depot 1 July 1954 – 30 June 1955*, volume 1.

The technology represented by reinforced concrete rigid framing, combined with thin-shell, reinforced concrete slabs, was cutting edge and, by definition, not perfected in 1951-1954. For the Special AMC Warehouse program, in particular, the experimental aspects of the construction technique required later refinements. One span of the rigid-frame system collapsed in the warehouses at Wilkins Air Force Station in Ohio (in August 1955) and at Robins Air Force Base in Georgia (in September 1956). (The Air Force had been aware of problems at Robins as of late 1954.) The structural failures were not catastrophic, but did garner immediate engineering attention.[222] Air Materiel Command directed the Army Corps of Engineers to hire yet another internationally prominent engineering firm, Ammann & Whitney of New York, to analyze the situation. Ammann & Whitney had been part of a team that examined the failing warehouses at Robins during autumn 1955, after the reported collapse at Wilkins. Ammann & Whitney prepared a revision of the original L.P. Kooken design in early 1956, a revision incorporated for all Special AMC Warehouses not yet built (such as the pair at McClellan) and one retrofitted into warehouses completed or still under construction. Swiss engineer Othmar Hermann Ammann had arrived in the United States in 1904, and is best known as a brilliant bridge engineer. As of 1946, Ammann partnered with Charles S. Whitney and, like Roberts & Schaefer, designed a number of key thin-shell domed and short-barrel reinforced concrete structures. The Ammann & Whitney thin-shell hangars for American Airlines and TransWorld Airlines (TWA) at Midway Field in Chicago of 1948 were the civilian counterparts to the SAC hangars by Roberts & Schaefer of mid-1947 at Ellsworth and Loring Air Force Bases. Ammann & Whitney discovered that the damaging cracks present in the Special AMC Warehouses had appeared either during construction or within the first two years following completion of the buildings. The firm's refinements have allowed the warehouses to continue as highly valued structures into the present day. The engineering community acknowledged the final 35 acres of Special AMC Warehouses, those at McClellan of 1956-1957, as remarkable.[223]

Yet at the conclusion of the Special AMC Warehouse program, Air Materiel Command still required more storage space. While the command never fully solved the problem of sufficient covered storage and shipping logistics, a first-phase of infrastructure was nearly in place by the middle 1950s. Capping the expansion, Air Materiel Command continued to experiment with building technology—again with the goal of massive size, construction speed, efficient cost, and, as is sometimes argued, improved aesthetics. During 1957-1958, the command required more warehousing for the Middletown AMA. Although Air Materiel Command had erected a Special AMC Warehouse at Olmsted Air Force Base several years earlier, materiel stored at the location was outpacing available space and the installation needed a modern runway for heavy aircraft. The situation was also steadily worsening as the command transferred personnel and materiel from the Shelby (clothing and textiles) and Topeka (toxic chemicals) depots to Middletown. The space deficit caused Air Materiel Command to temporarily lease storage areas at the Mechanicsburg Naval Depot nearby. The command was in the early stages of phasing out its special depots, such as Shelby. Items like liquid oxygen tanks, stored at Shelby, were also soon enroute to Middletown, to become the responsibility of the Directorate of Air Force Petroleum there. In a final complication, the Middletown AMA was responding to a Department of Defense directive of 1955, one stipulating a hardened storage program for petroleum installations.[224]

Through the Baltimore District of the Army Corps of Engineers, Air Materiel Command looked at alternate designs for a large warehouse complex at the Middletown depot to respond to its rising needs. Simultaneously the command constructed a 10,000-foot reinforced concrete runway for Olmsted Air Force Base, 13 to 21 inches thick and parallel to the Susquehanna River. The Harrisburg municipal airport was immediately adjacent. The needs of Air Materiel Command for more warehouses, and for hardened petroleum storage (discussed as underground or bunkered), led to the selection of an annex-like site completely segregated from the installation, although in its vicinity.[225] The Corps specified that architects consider both the reinforced concrete rigid-frame, precast system

using thin-shell panels then definitive for the Special AMC Warehouse, and a system looking back toward the Roberts & Schaefer (Anton Tedesko) long-barrel thin-shell warehouse favored by the Air Corps and the Army Air Forces during the early 1940s. Air Materiel Command selected Roberts & Schaefer to submit these designs.[226] By this date Tedesko, still a leading engineer of thin-shell construction, was serving as a formal advisor to Headquarters Air Force (since 1955).

Roberts & Schaefer thoroughly tested its ever-thinner shell construction in mockup partial-scale models prior to employing its improvements in real-world buildings. Observation of structural behavior, rather than a pure reliance on mathematical theory, was primarily a European practice—and is evidenced in the work of the period's finest Swiss, German, French, Italian, and Spanish engineers, including Freyssinet, Finsterwalder, Maillart, Nervi, and Torroja. As early as 1950, Tedesko had directed construction of a scaled model for a concrete ribless barrel shell on Roberts & Schaefer property in southside Chicago (Harvey, Illinois).[227] The firm staged dramatic tests of the new ribless thin-shell, long-barrel construction, with accompanying photographs that showcased large groups of employees standing atop the model. These tests (and the photographs of them) paralleled what Franz Dischinger, of Dykerhoff & Widmann, had first used to illustrate the strength of the thin-shell technology in Biebrich, Germany, during the summer of 1931. Remarkably, the post-World War II ribless shell was the idea of not just Tedesko, but of Tedesko and Dischinger together. Both the Americans and the British had sought to remove or recruit Dischinger from Germany during 1947-1948 to enhance their own military civil engineering programs. Specifically, Air Materiel Command wished to have him for work toward heavy, reinforced concrete, bomb-proof construction (see Volume I, Part III). Dischinger had directly participated in Nazi civil engineering (notably, hangars and heavily protected submarine pens), and could not be easily removed from Germany. Instead, Dischinger was allowed to teach in the Technical University in West Berlin (a university founded in 1946) until 1951.[228] Tedesko and Dischinger developed the basis of ribless, thin-shell construction through correspondence in 1950,[229] picking up such professional communication where it had left off in the late 1930s and *ipso facto* pulling Dischinger into the service of Air Materiel Command for progressive engineering—a truly stunning continuity both in terms of engineering and politics. The collaboration between Tedesko and Dischinger supportive of Air Materiel Command's needs also foreshadowed a role of the ARDC European Research Office in Brussels. In place as of August 1952, that office employed 30 people as of 1958, letting unclassified contracts to foreign contractors and financing research at foreign universities.[230]

The meticulous pretesting and analysis by Roberts & Schaefer during the early 1950s was perhaps especially attractive to Air Materiel Command after the partial failures at Wilkins Air Force Station and Robins Air Force Base during 1955-1956. As of mid-1957, the command accepted the innovative ribless, long-barrel thin-shell design of Roberts & Schaefer for a 640,000 square-foot warehouse complex at Olmsted Air Force Base (Plate 34). The huge set of end-to-end warehouses was under construction by August 1957, with completion in 1959. The two structures used 16 cast-in-place ribless shells, each 200 by 200 feet in size.[231] Still referenced as "special AMC warehouses" by the command, the two structures maintained the 400-foot modular width of the Special AMC Warehouse designed by L.P. Kooken in 1951. One warehouse was 400 by 1,200 feet in its dimensions, the other 400 by 400 feet.[232] The Assistant Chief of Staff, Installations, at Headquarters Air Force was also involved in the new warehouse design at Olmsted. In mid-1957, the headquarters civil engineering unit noted that the Air Force had selected the "thin-shell concrete arches" partially to "overcome structural deficiencies with the standard AMC warehouse structures [the Special AMC Warehouse]," and that the Olmsted pair were a test for usage across Air Force bases world-wide. Of particular interest, the Assistant Chief of Staff, Installations, linked the long-barrel, thin-shell construction to the need to design facilities resistant to the effects of nuclear detonations.[233] This final pair of experimental warehouses for Air Materiel Command of 1957-1959 had a value of just under six million dollars.[234] Added to its other growing responsibilities, the command assigned the

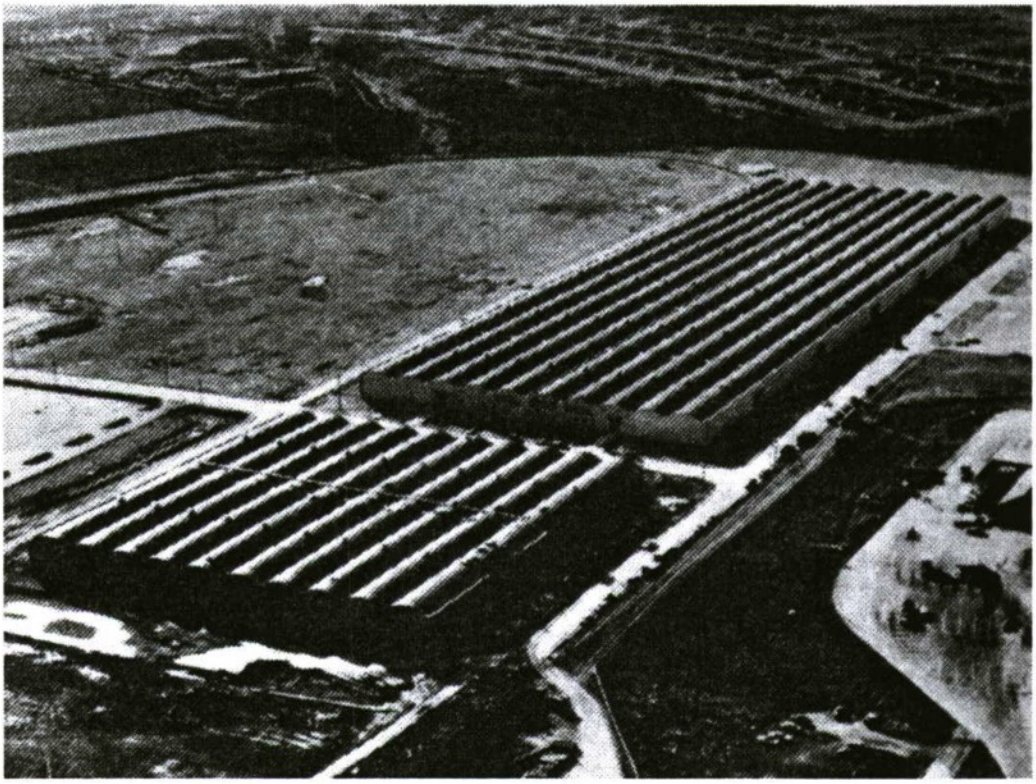

Plate 34: Anton Tedesko (Roberts & Schaefer). Warehouse for the Middletown AMA at Olmsted Air Force Base, Pennsylvania. As completed in 1959. In *Journal of the Structural Division, Proceedings of the American Society of Civil Engineers*, November 1982.

Middletown AMA the Headquarters, Air Procurement Region, Europe, with its eight detachments, between July 1962 and April 1963.[235]

The rise of the ballistic missiles program within the Air Force during the middle 1950s also affected Air Materiel Command, as immediately as it had ARDC. With the top priority status of the Atlas ICBM project as of autumn 1955, ARDC had established its WDD in Los Angeles. Air Materiel Command activated a counterpart unit, the Special Aircraft Project Office within the Directorate of Procurement and Production. By early 1956, Air Materiel Command had renamed its first ICBM unit more aptly as the Ballistic Missiles Office, a unit designated to handle missile logistics functions. At first the office was primarily a Headquarters Air Materiel Command effort at Wright-Patterson, with a small Southern California contingent. By autumn 1958, however, the Ballistic Missiles Office had become the Ballistic Missiles Center, with authority equivalent to a numbered Air Force and its commander directly reporting to the commander of Air Materiel Command. The Ballistics Missiles Center performed procurement, production, supply, and maintenance functions for ballistic missiles and space vehicles. The center partnered its efforts with ARDC and was physically collocated with the R&D unit from 1954 until late 1960, when the Ballistic Missiles Center moved to Norton Air Force Base.[236] Simultaneously, Air Materiel Command assigned specific AMAs support tasks for the whole of a missile weapons system. AMAs had the responsibility of supplying and maintaining the airframes for the missiles, as well as providing for their storage. As of mid-1957, Air Materiel Command tasked the San Bernardino AMA at Norton with the Atlas, Titan, and Thor missiles, and associated target drones. The Ogden AMA at Hill received responsibility for the strategic cruise and interceptor missiles; the Warner Robins AMA at Robins, tactical missiles; the Oklahoma City AMA

at Tinker, guided air missiles; and, the Middletown AMA at Olmsted, guided air rockets. Very little repair and maintenance on the missiles occurred in the field during this early time, with most missiles air-shipped to their contractors or to the appropriately assigned AMA depot.[237] Aircraft weapon systems assignments, in a so-called family-group policy, paralleled those of missile packages as of late 1957. Air Materiel Command assigned all new fighter aircraft to either the Sacramento or Mobile AMAs; bomber and tanker aircraft to the San Antonio or Oklahoma City AMAs; cargo and transport aircraft to the Warner Robins or San Bernardino AMAs; and, liaison, trainer, and miscellaneous aircraft, as well as helicopters, to the Middletown AMA.[238]

Restructuring and organizational practice within Air Materiel Command during the late 1950s continued to move forward under the business-influenced management style of its commander, General Rawlings. The command adopted an increasingly systems approach, wherein the entire process of the procurement, supply, and maintenance for a weapon or aircraft became linked, with an emphasis on fluid interaction to solve problems and to achieve a high level of synchronization. Paralleling the systems influence in creating the Ballistic Missiles Office, with its nerve center in Los Angeles, was the establishment of the ASC at Wright-Patterson in September 1958. In this case, personnel from the weapon systems project offices moved to Headquarters Air Materiel Command, rather than shifting outwardly to the field as had been true with the Ballistic Missiles Office. Simultaneously, ARDC retitled two of its units parallel to the restructuring within Air Materiel Command, creating the WADD (1959) and the AFBMD (1957). In late 1959, a final pairing of sister units within Air Materiel Command and ARDC came into being, focused on electronics. Air Materiel Command's Electronic Systems Center became the counterpart to a retitled unit within ARDC, the AFCCDD—with both organizations physically located at Hanscom Air Force Base. For Air Materiel Command the idea was to shift focus to the entire system involved, and not to separate procurement, supply, and maintenance actions by components. For example, Hanscom's Electronics Systems Center of 1959 handled the entire Semi-Automatic Ground Environment (SAGE) computerized command-and-control system for air defense, while pieces of communications electronics equipment below the system level became the responsibility of the Ground Electronics Engineering Installation Agency (GEEIA) headquartered at the Rome depot in New York. GEEIA installed equipment at difficult sites, also adjusting and improving it. Air Materiel Command was the executive manager for the agency within the Air Force, establishing mobile depot-like units to handle maintenance for the equipment that GEEIA set up. GEEIA, like Air Materiel Command, operated through defined ground electronics regions.[239]

The most confusing changes in the overall restructuring within Air Materiel Command and ARDC were those tied to missiles and space systems. The Air Materiel Command lineage moved from the Special Aircraft Project Office, to the Ballistic Missiles Office, and finally to the Ballistic Missiles Center. The paralleling ARDC lineage evolved from the WDD, to the AFBMD, to a split in 1961 as the Space Systems Division and the Ballistic Systems Division with the creation of AFSC. Also with the change from ARDC to AFSC, and Air Materiel Command to AFLC, in 1961, the three product centers of Air Materiel Command shifted to AFSC—with the Ballistic Missiles Center absorbed into the Ballistic Systems Division. Although very close in their names and periods of existence, the Ballistic Missiles Office, Ballistic Missiles Center, (Air Force) Ballistic Missile Division, and the Ballistic Systems Division were each distinct, with the first two units in Air Materiel Command and the second two units in ARDC / AFSC. During the early years too, Air Materiel Command / AFLC and ARDC / AFSC consistently ran their ballistic missiles missions at a shared site, in a situation that continued even after AFSC organized its missiles and space responsibilities together within SAMSO in 1967 (see Volume II, Chapter 9).

A strong movement to reorchestrate activities shared between Air Materiel Command and ARDC characterized the late 1950s. As of 1958, Air Materiel Command desired assignment of engineering

responsibilities for weapons and aircraft systems that had reached permanent status. General Rawlings and the commander of ARDC, General Anderson, signed a realignment agreement between the two commands early in the year, an act that initiated the transition toward the three sister units focused on ballistic missiles, aeronautical systems, and electronics. The reorganization of ARDC into AFSC, and Air Materiel Command into AFLC, in April 1961, thus affirmed organizational directions already underway.[240] Complementary with the shift to systems management, Air Materiel Command also overhauled its depot structure beginning in 1958—just as buildout for the Special AMC Warehouse and the thin-shell ribless warehouse at Olmsted reached completion. While the command had closed two special depots before mid-decade (those in Kansas City and at Fairchild Air Force Base in Spokane), the remainder of the network had maintained a status quo. At the outset of the decade, the push had been for much more storage space. By the decade's close, the command felt that "faster transportation, transceiver networks, and electronic data processing allowed...managers to control commodities which were dispersed to base level, reducing the need for depot stocks and warehouse space."[241]

Once more, private industrial business practices foreshadowed those of Air Materiel Command. General Rawlings wanted one-fourth of the storage depots closed, in an action that would cut costs from about $29 million a year to less than $6 million. The command carried out the process in two phases, first transferring management functions to the depots gaining responsibility and second moving materiel. Depot inventories were to drop through attrition and disposal, rather than through one large shift. When inventory was sufficiently low at a depot going through closure and when its remaining items were ear-marked for only a single location (rather than for dispersal to multiple depots), then the closing depot became an annex or off-base site attached to a remaining AMA.[242] As of early 1958, Air Materiel Command closed the Gadsden Air Force Depot in Alabama, which became an off-base facility of the Mobile AMA. In 1960, the command continued cut-backs with the closure of Cheli Air Force Station in Los Angeles; Mallory Air Force Station in Memphis; and, the Air Force Depot in Topeka. To offset some of these actions, Air Materiel Command elevated the depot at Rome, New York, back to primary AMA status. The Rome AMA operated without geographic boundaries, an anomaly in the continental United States.[243] By the close of 1960, Air Materiel Command featured 11 AMAs—climbing back sharply toward the 12 geographic areas of World War II, but including two overseas areas. The command also included the three systems centers of 1958-1959; three contract management regions (western, central, and eastern); two special depots, both in Ohio (Wilkins in Shelby and Gentile in Dayton); and, the 3079th Aviation Depot Wing managing the group of nuclear materiel storage installations[244] (Plate 35). In January 1961, immediately before the change from Air Materiel Command to AFLC, Wilkins Air Force Station in Shelby closed. Gentile Air Force Station in Dayton remained the only special, independent depot in the command as it entered the AFLC era.

Under Air Force Logistics Command: 1961-1992

The transition from Air Materiel Command to AFLC occurred during the buildup for the Vietnam War. Eglin Air Force Base began actively training men for deployment to Vietnam as of April 1961—the same month as the official restructuring of Air Force R&D and supply-logistics. In that regard, preparations at Eglin quickly required the direct support of AFLC to refurbish selected World War II aircraft for the effort. After this first step, both AFSC and AFLC heavily contributed to Air Force needs in Southeast Asia. The predicted requirements of procurement, supply, and maintenance for both aircraft and weapons escalated as the war unfolded, and yet the newness and scale of counterinsurgency tactics and a jungle environment fostered substantially different parameters of conflict from those experienced in Asia during World War II and Korea. Decisions of restraint for nuclear materiel surfaced early. Pressures to build air bases quickly and efficiently were

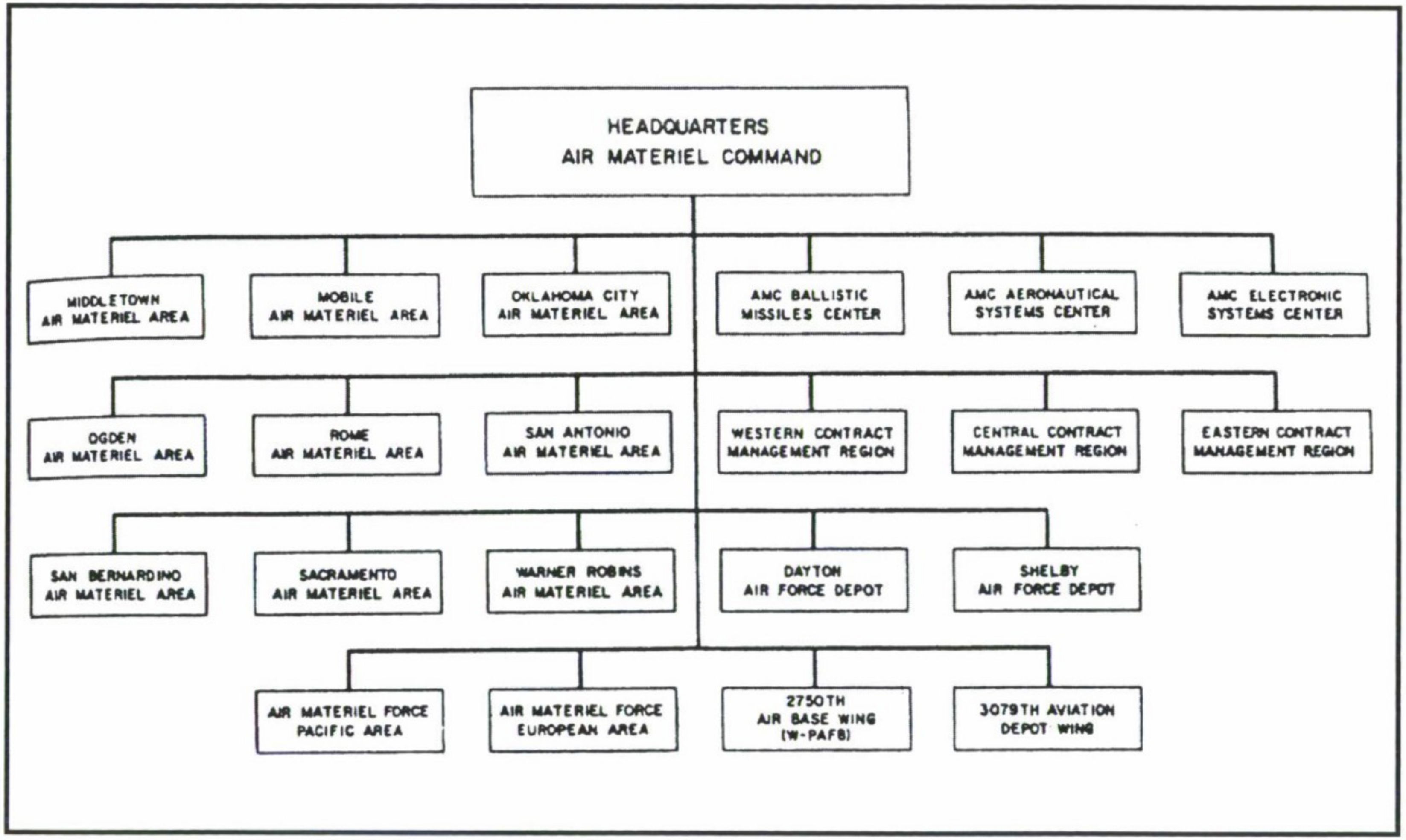

Plate 35: **Air Materiel Command, Organization Chart, November 1960. In** ***Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition (1950-1986)*****, volume 1.**

immediate. Training the South Vietnamese, and attempting to fight a war fully on behalf of another culture, raised yet other issues. For AFSC, research, development, testing, and evaluation of protective aircraft revetments and shelters was a massive program that required parallel action by AFLC. The primary depots of AFLC stored revetments and shelters that personnel had broken down into their respective parts. The command shipped bundled components of the structures to Vietnam for erection at installations there (Plate 36).

An even further-reaching program of the Vietnam War focused on prefabricated infrastructure, everything from airmen dormitories to equipment shops. The concept of Bare Base originated during the late 1960s. Working with TAC, AFSC defined Bare Base as "multiple modular or expandable units, packaged as containers, essentially designed and engineered to replace personnel tents and aircraft hangars where deployed...a 'Runway, A Source of Water and Nothing Else.' " Hundreds of prepackaged structures were in storage at AFLC depots, and featured materials ranging from lightweight metal and plywood, to inflatable synthetic cloth. Portability was key, as was fast, successful erection by unskilled labor combined with AFLC teams of civil engineers known as Prime BEEF (Base Engineering Emergency Force). One double-walled, inflated structure folded up into 18 three- by four- by five-foot boxes.[245] Later, as current-era aircraft replaced refurbished World War II planes, AFLC depots shipped many aircraft too. Personnel initially stored them as aircraft bodies and separated wings, sitting uncovered and tightly packed inside revetments at Vietnamese bases. AFLC also sent rapid-repair teams to Vietnam to handle crashed aircraft and damaged infrastructure, particularly to refurbish bombed runways.[246]

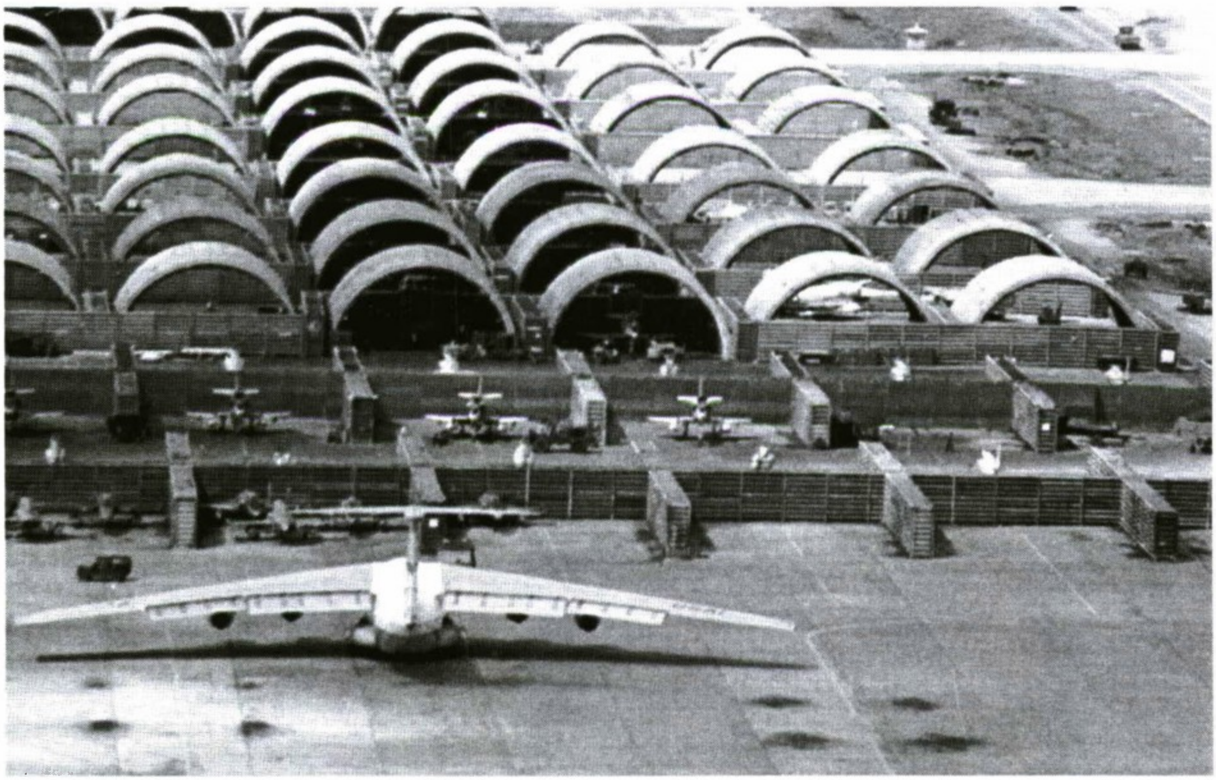

Plate 36: Aircraft Revetments and Concrete Sky Aircraft Shelters, Bien Hoa Air Base, Vietnam. Project Enhance Plus, 9 November 1972. Courtesy of the History Office, Hill Air Force Base.

AFLC continued to streamline its depot system in the continental United States during the decade of the 1960s, even while preoccupied with the efforts in Vietnam (Plate 37). As of 1962, management of the nuclear materiel storage depots transferred from AFLC to SAC. By mid-1962, AFLC closed the special depot in Dayton, and the Gentile Air Force Station continued operations primarily through the Defense Logistics Agency, a tenant.[247] (The Air Force procured many standard items through the General Services Administration, the Defense Logistics Agency, and the Departments of the Army and Navy. These agencies and military service arms, like AFLC, required warehouses.) Plans to close four of the nine AMAs were in place by late 1963. The first depot to shut down was San Bernardino in July 1966. Norton Air Force Base transferred to Military Airlift Command (MAC), while the depot's missiles functions transferred to Ogden. The second of the AMAs to inactivate was the depot at Rome, New York, which terminated in April 1967. AFLC transferred Rome's logistics functions to the depots at Oklahoma City, San Antonio, and Sacramento. (Griffiss Air Force Base, the host installation for the Rome depot, became a SAC installation in mid-1970, with AFSC continuously sustaining the R&D electronics laboratories on site.) AFLC inactivated the Middletown AMA next, in October 1967. Middletown's functions moved to Warner Robins (aircraft) and Ogden (missiles). The base fully closed with the cessation of AFLC activities, an irony given the emphasis placed on the installation less than a decade earlier.[248] The situation was similar for the Mobile AMA at Brookley Air Force Base. Mobile's aircraft and drone systems went to Warner Robins and Sacramento, while a more diverse group of supply functions transferred to Wright-Patterson, San Antonio, Warner Robins, Ogden, and Oklahoma City. Brookley closed after conclusion of its AFLC depot mission in June 1969, thereafter adapted for civilian reuse.[249]

Downsizing, coupled with the draining of resources to support the Vietnam War and progress in missiles technology (hence in logistics requirements), brought AFLC full circle by the early 1970s. Over time, the AMA and depot system had alternated in its organizational size: shrinking (immediately post-World War II); reexpanding (1950-1959); shrinking again (1960-1969); and, as of FY 1972, requiring serious upgrading due to inadequate available storage and lagging warehouse practices. AFLC was a very, very large business, quite unlike other commands within the Air Force, and strongly parallel to a monolithic industry wherein change drives efficiency but sheer size makes innovation somewhat out of cycle. The Depot Plant Modernization Program, beginning in late 1972, continued through about 1976 and focused on building projects. Immediately following, the Depot Plant Equipment Program of FY 1977 funded new equipment. The Logistics Improvement of Facilities and Technology Program picked up the efforts again in 1979 with an emphatic "use of advanced technology and the application of the systems approach to industrial processes."[250] Improvements and streamlining of technology continued through the next decade.

Transition from Air Force Logistics Command to Air Force Materiel Command

At the end of the Cold War, AFLC still maintained its 1970 configuration of five geographic areas, each with a primary depot. Air Logistics Centers (ALCs) had replaced the terminology of the long-standing AMAs. ALCs included Ogden (OO-ALC) at Hill Air Force Base, Oklahoma City (OC-ALC) at Tinker Air Force Base, Sacramento (SM-ALC) at McClellan Air Force Base, San Antonio (SA-ALC) at Kelly Air Force Base, and Warner Robins (WR-ALC) at Robins Air Force Base. In 1991, AFLC also maintained 18 specialized centers, most of which were located at Wright-Patterson. This organizational structure continued after AFLC and AFSC reunited into the single command, AFMC, in mid-1992.[251] During 2000-2001, AFMC further consolidated the remaining depot functions. McClellan Air Force Base fully closed, with its real property adapted for civilian reuse. The Air Force realigned a portion of Kelly with its neighboring installation, Lackland Air Force Base, and turned over the remainder of the installation to the city of San Antonio. Closure of McClellan and Kelly was counter to the wishes of AFMC. The command, supported at Headquarters

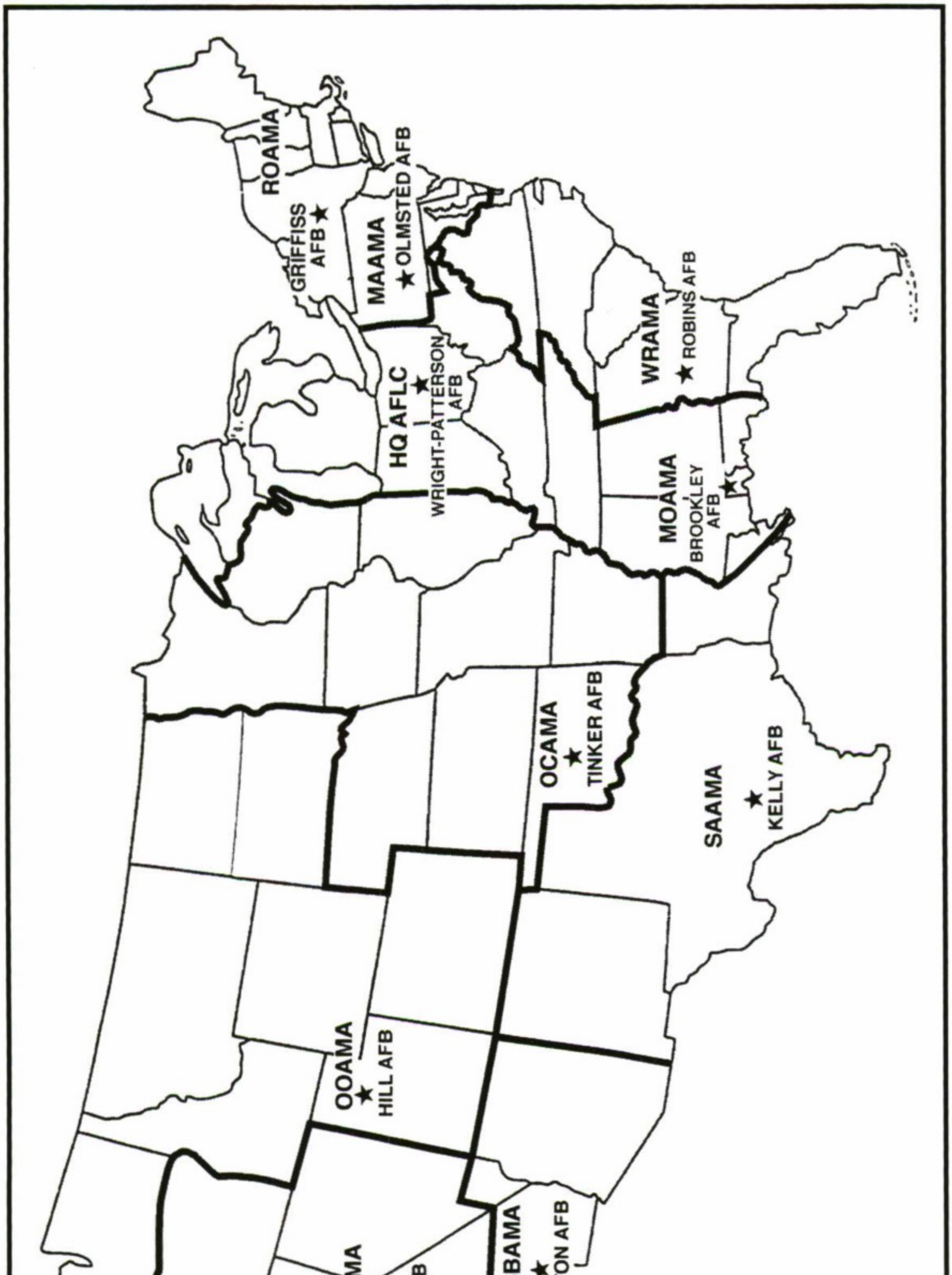

Plate 37: AMA Areas of Responsibility, 1962-1963. Adapted from *History of Warner Robins Air Materiel Area 1 July 1962 – 30 June 1963*, part IV.

Air Force, had recommended "downsizing in place" for both bases. The 1995 Base Realignment and Closure (BRAC) Commission had rejected the Air Force position, forwarding a recommendation of closure for the SM-ALC and the SA-ALC to Congress and the President. Congress then enacted the BRAC recommendations into law.[252]

Industrial Plants

During World War II

The Army subsumed aircraft and related weapons procurement for the Air Corps and the follow-on Army Air Forces within the functions of these service arms' Materiel Division and Materiel Command. With headquarters at Wright Field, procurement addressed more than 100 aircraft models during the war, attaining a maximum on-the-shelf inventory of nearly 80,000 planes. Wartime production reached a total of just under 300,000 aircraft, as well as approximately 800,000 each of engines and propellers. The industrial buildup linked the Army closely to private industry, with adaptation of factory production line practices.[253] During the war, two types of industrial facilities existed: government-owned, government-operated plants and government-owned, contractor-operated plants. The latter type of plant, commonly known as a GOCO, was the paradigm for the Army aircraft plant, with the huge investment for the infrastructure—either fully new or converted from other large industrial manufacturing—substantially financed by the federal government. Government funded aircraft plants (Army and Navy) totaled 350 before the end of the war.[254] Construction for GOCO aircraft plants in the United States began in mid-1940, immediately following President Franklin Roosevelt's declaration of "an unlimited national emergency" in late May and the announcement of the Protective Mobilization Plan in June. Britain and France had officially entered the war with Germany in September 1939, although the Nazi rise had occupied much of the preceding decade.[255]

Speed of construction, as well as the very high caliber of the industrial architectural-engineering firms responsible for plant design, were hallmarks of the World War II aircraft manufacturing program. Aircraft plants typically adjoined existing municipal or military airfields, with runways immediately accessible to the manufacturers. The Army issued contracts as of early June 1940, with the first plants heralded in engineering journals. Commentary included: "built in 40 [working] days," in reference to Pratt & Whitney's quadrupling of a 1930 aircraft engine plant at East Hartford, Connecticut, and, "fifteen-acre plant for bombers built in 90 days," describing Boeing's addition to an existing plant of 1936-1937 in Seattle.[256] Contractual clauses stipulating plant completion within 110 days were not uncommon.[257] Many of the plants set up for the manufacture of aircraft engines were those of the automotive industry,[258] and it is not surprising that the leader in design and engineering for the sophisticated, modern assembly-line aircraft manufacturing plants was the firm of Albert Kahn in Detroit.[259] Kahn's largest industrial client was Ford, including plants built for the automotive giant overseas. Albert Kahn was also the architect for the large Air Transport Squadron hangars built for the Army as of 1940-1941.[260] Design parameters common to both the aircraft plants and the hangars were large, open interior spaces (clear spans) and repeated modular units. The latter feature allowed for economical expansion or repeated buildout. Most aircraft plants were single-story, featuring uniform daylight (before requirements for blackout plants and stable, cool inside temperatures) with a reliance on curtain walls with banks of steel-sash fenestration. With the need for windowless plants, air conditioning and fluorescent lighting became the norm for 24-hours-a-day operation.

Although Kahn's work was most well known, other important architectural-engineering firms also participated in innovative design for the aircraft plants. One key engineering firm—sometimes

selected along with a consulting architectural firm—was J. Gordon Turnbull of Cleveland.[261] Designs for two of Turnbull's plants, for North American Aviation in Dallas and Kansas City, featured unusual exterior walls. The lower portion of the walls was reinforced concrete, 12 inches thick to a height of 5.5 feet. Above this level, the wall structure relied on a cellular sheet-metal siding. The sheet-metal portion of the exterior walls was vertically corrugated, fiberglass-insulated, and interlocking.[262] After the war, Turnbull would work on Air Materiel Command's underground pilot plant project for aircraft manufacturing. In 1948 he interviewed engineers in Germany on the particulars of heavy, bomb-proof construction, sponsored by the command (see Volume I, Part III). Other major architectural-engineering firms included the preeminent bridge engineers, the Austin Company of Cleveland, and Giffels & Vallet, a Detroit firm most involved in the engineering of military munitions storage facilities. Giffels & Vallet, working with architect L. Rossetti, also designed award-winning Pratt & Whitney aircraft engine plants for Ford Motor Company, a client more typically Kahn's. The Giffels & Vallet partnership with Rossetti was responsible for major R&D laboratories in the late 1940s, and would handle multiple high-level Air Force assignments as Giffels & Rosseti as of the 1950s. The Cold War assignments included ones for Headquarters Air Force and for SAC.[263]

Journalists always described the quantities of building materials required for plant construction in "tons [of concrete and structural steel]," "millions [of bricks in a curtain wall]," acres [of roofing and window sash / glass]," and "thousands [of man-days for labor]." By mid-February 1941, 38 aircraft and aircraft engine manufacturing plants were underway. Kahn's firm designed 10 of these plants (Plate 38); Austin Company, six; Giffels & Vallet, two; and, J. Gordon Turnbull, two.[264] (Albert Kahn Associates designed a total of 41 defense production plants in the continental United States between 1929 and 1945.[265]) When construction for full-scale aircraft plants turned to the Southeast in 1942, another major architectural-engineering company joined the group: Robert & Company of Atlanta. Robert & Company's showcase plant was that built for Bell Aircraft in Marietta, Georgia.[266] As was true for the other firms hired to design the exceptionally large modular structures with long interior clear spans, Robert & Company went on to handle similar engineering problem sets for Air Materiel Command. One example of Robert & Company's efforts was the climatic hangar at Eglin Air Force Base in 1944. The final assembly bay of the Bell plant at Marietta featured an interior clear span of 300 feet, while clear span for the climatic hangar at Eglin was just under 250 feet.[267]

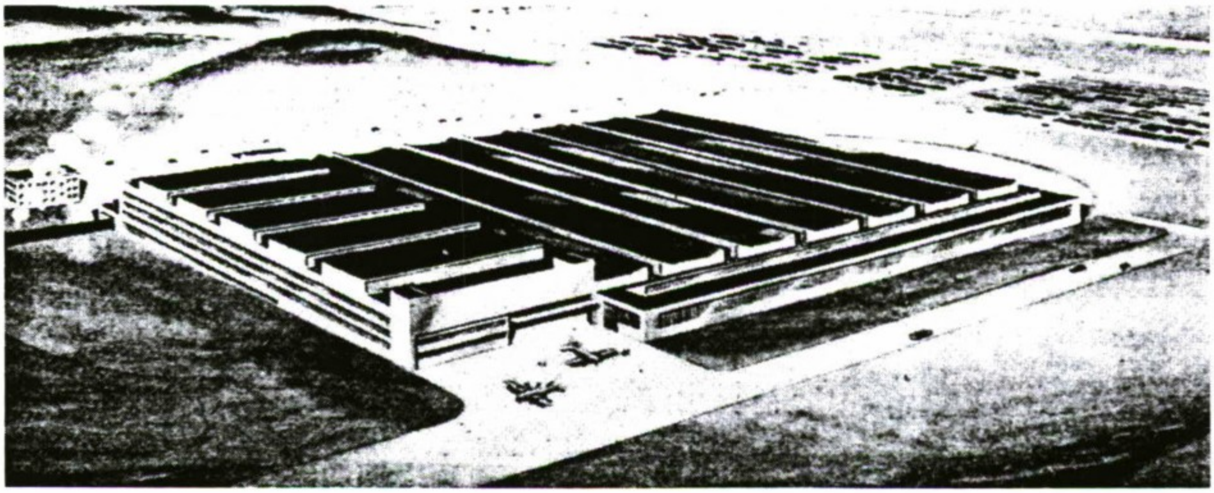

Plate 38: Albert Kahn. Glenn L. Martin Aircraft Plant (Government Aircraft Plant No. 1), Offutt Air Force Base, Omaha, 1941. In *Engineering News-Record*, 10 April 1941.

After the Japanese attack on Pearl Harbor in December 1941, the United States formally entered World War II, joining the Allied powers against Germany, Italy, Japan, and their aligned Axis group. Construction for aircraft and aircraft-engine plants for Materiel Command entered a new phase, with an enhanced urgency for all industrial mobilization. Also of immediate concern was aircraft modification for wartime. The Army Air Forces, through a Procurement Division Modification Program within Materiel Command, established procurement modification centers to outfit combat and training aircraft with specific improvements. Modification centers complemented aircraft production plants, facilities that were already under tremendous strain to meet demand. The Army Air Forces decided that a slowing of production to integrate aircraft modifications at the plants would have resulted in fewer overall planes manufactured. Modification centers, typically operated by both aircraft and airline companies, also helped offset the loss of planes from the private sector to the federal government. In particular, production modification centers provided work for airline shops at the outset of the war. Modification centers were both "basic" and "special." Basic modification centers handled uniform changes to all aircraft of a specific type: "such as the substitution of the B-17 chin turret for the hand held .50 caliber guns." Special modification centers took on tasks such as the conversion of a B-24 into an F-7, or adding radar, camouflage, and armament appropriate to theaters of operation (or to conditions like night flying).[268]

At the end of World War II, 21 production modification centers were operational, with 15 still functioning in early 1946 and with all ceasing activities shortly after the war's end. Vandalia Army Air Field had supported a modification center and a propeller factory during the war (see Volume II, Plate 187), with its eight laminated wooden-arch hangars similar to those built for a Northwest Airlines modification center near St. Paul, Minnesota.[269] As of February 1945, the airlines running production modification centers were those of United in Cheyenne, Wyoming; Continental in Denver; and, Northwest in St. Paul. At the height of the war, Eastern, American, Transcontinental, Western, Delta, and Pan American also participated in aircraft modification for the Army Air Forces. Aircraft companies operating modification centers included Curtiss-Wright in Buffalo, New York; Bell in Niagara Falls, New York; Boeing in Denver (with Continental); Douglas in Oklahoma City and Tulsa; Glenn L. Martin in Omaha; North American Aviation in Kansas City; Republic Aviation in Evansville, Indiana; Consolidated-Vultee in Louisville, Kentucky, and, Tucson; and, Lockheed in Dallas. A consortium of three companies, Bechtel, McCone, and Parsons, ran the largest production modification center of all, in Birmingham, Alabama.[270]

As of 1942, the federal government forbad all "nonessential civilian construction," with the building industry working fully to support the war effort. In May, the War Production Board, directed by the Secretaries of War and Navy, implemented a policy whereby all military construction projects met wartime criteria. Projects were to be "essential;" unable to be postponed; irreplaceable by rented or leased facilities; of economic design and construction; and, as simple as was feasible.[271] These criteria reinforced the modular, repetitive construction already going forward. Such parameters perhaps also encouraged pushing the boundaries of modern-era design and engineering technology. As of late 1944, the American engineering profession identified those buildings that would offer key "wartime lessons for peacetime building." Highlighted was the work of Kahn and the Austin Company for aircraft manufacturers, Anton Tedesko for the Navy and the Army Air Forces, Fred Severud for the Army Air Forces, and, Arsham Amirikian for the Navy.[272]

Achievements were many and varied, with most applicable to the Cold War period ahead and many directly adopted by Air Materiel Command. Innovations included:

- wide clear spans;
- steel framing and trusswork;

- thin-shell, concrete barrel construction;
- combined concrete column-and-girder systems;
- hollow, reinforced concrete box girders;
- wooden trusswork, with a focus on laminated beams and arch ribs;
- plywood plate girders;
- precast concrete panels as exterior facing;
- fiberglass-insulated steel panels;
- major improvements in interior lighting—from extensive use of fluorescent fixtures to that of incandescent and mercury vapor units;
- white concrete flooring and white ceilings to magnify even indirect light;
- air conditioning, uniformly applied; and,
- ventilation for windowless buildings.

The laminated technique, sometimes called lamella, illustrated particular creativity with limited materials. Severud, Amirikian, and Tedesko made recognized contributions in this arena, as well as those for which they are best known.[273] While the Army's aircraft and aircraft-engine plants went forward from 1940 to 1944, it is of note that the Army's Chemical Corps, the Army Air Forces, and the NDRC also jointly pursued a highly developed understanding of the design and engineering of enemy industrial plants to increase bombing accuracy. For the latter endeavor, from late 1942 into 1944, factory targets at the Edgewood Arsenal in Maryland and on Eglin's Range 52C complemented the real-world building program going forward simultaneously[274] (Plate 39).

By the end of the war in 1945, 12 large GOCO plants were in place to manufacture heavy bombers for the Army Air Forces. Boeing produced the B-17 and the B-29, in operations that occupied fully seven of these plants. The company manufactured the B-17 in Seattle and at two licensed plants in Southern California. The firm directly ran two plants for the B-29 in Everett, Washington (adjacent to the Army's Paine Field), and in Wichita, Kansas (the future McConnell Air Force Base). Boeing also licensed additional B-29 manufacture through Bell Aircraft in Marietta, Georgia (adjacent to the future Dobbins Air Force Base), as well as B-26 manufacture through the Glenn L. Martin Company in Omaha, Nebraska (at the future Offutt Air Force Base). Consolidated Aircraft (later Consolidated-Vultee, and then Convair) manufactured the B-24 in San Diego, California; Fort Worth, Texas (at the

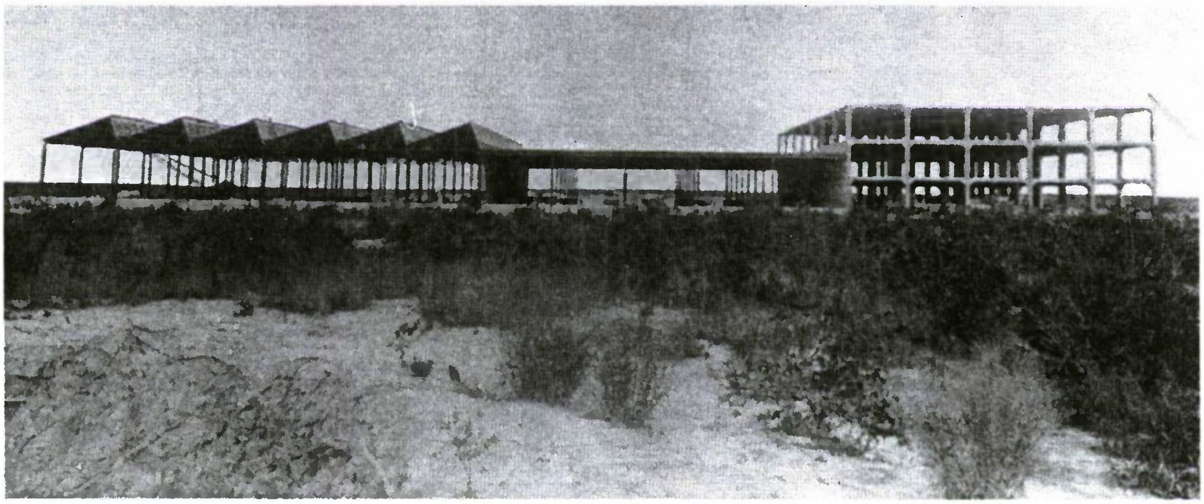

Plate 39: NDRC German Industrial Test Structure (Factory Target), Range 52C, Eglin Field, 1944. In *Fire Warfare. Incendiaries and Flame Throwers*, 1946.

future Carswell Air Force Base); and, under license to other companies, at Willow Run (west of Detroit), Michigan; Tulsa, Oklahoma; and, Dallas.[275] Another 23 military aircraft production plants expanded the total number of such facilities to 35 as World War II ended.[276]

Change and Evolution during the Cold War

Following the surrender of Japan in September 1945, the aircraft and weapons systems procurement mission abruptly changed, with many contracts cancelled and plant production shut down. The federal government desired that a smooth transition into a peacetime economy give the government its best dollar and that corporations return quickly to production of private sector goods with strong profits. Long years of economic depression and wartime necessity left the public with an equal need to resume healthy spending. The problems that arose, however, were many. Fifteen major companies produced airframes, engines, and propellers for the military and commercial airlines as of the late 1940s.[277] The federal government sought to sell its GOCOs to the companies that had operated them as government manufacturing sites during the war effort. In selected cases, this scenario played out well, but in others it did not. In heavily industrialized areas, components plants, for example, could be converted easily to peacetime product manufacture. For the large aircraft plants, however, high-bay production space did not readily translate to automobiles or other large-item manufacture. These facilities were of even more difficult conversion for smaller product assembly. The civilian aircraft industry faced its own challenges post-war, and could not immediately support the major new manufacturing of planes.

In many instances, neither the Army Air Forces nor the Navy could sell government-owned aircraft manufacturing plants, instead keeping them as a part of leased or mothballed inventory through the War Assets Administration.[278] One example of the post-war cautionary tale was that for the Curtiss-Wright plant in Columbus, Ohio. Curtiss-Wright had built the plant as a GOCO to manufacture the SB2C Helldiver, a Navy tactical fighter-bomber. Immediately after the war, the company tried to continue using the plant profitably, at first producing three experimental aircraft there. Only one year after the war, Curtiss-Wright contracted with Air Materiel Command to overhaul the B-29 and the C-46. In 1947, Curtiss-Wright could no longer sustain the plant and the Navy mothballed it. The next attempted use of the facility was that of the Lustron Corporation of Chicago. Lustron manufactured prefabricated steel-frame houses sheathed in porcelain-enameled steel panels. The company leased the plant from the War Assets Administration (an agency functional into mid-1949), although the plant remained Navy property. (During the late 1940s at least 10 aircraft manufacturers expressed formal interest in converting plants for the manufacture of prefabricated housing.) The Reconstruction Finance Corporation (RFC), another federal agency managing property post-war, foreclosed on Lustron in early 1950 and the Columbus Curtiss-Wright aircraft plant passed from the Navy to the Air Force.[279]

Although Air Materiel Command cut back its aircraft procurement program in 1946 to 10 percent of what it had been in 1945, the command did press forward with a few contracts. Air Materiel Command directly continued only two war contracts, for the B-29A (54 planes on order from Boeing) and the B-36A (87 planes on order from Consolidated-Vultee). During 1946, the command let a new contract for 60 B-50s, a Boeing bomber upgraded from the B-29. During FY 1947, Air Materiel Command contracted for yet more B-50 production, adding 73 planes to the Boeing order. The fourth post-war bomber contract was for 96 North American B-45As during 1947-1948. The early Cold War also required significant production of new jet fighter aircraft, concentrated on the P-80 series (Lockheed and North American) and the P-84 (Republic). Over 1,500 fighters were in production at the end of 1946. Air Materiel Command contracted for transport planes minimally in the post-war months, with some continuance of liaison and rotary wing aircraft. The command completely stopped production of trainer aircraft, but did fund prototype and experimental work for 13 different

planes. The command's long-range experimental aircraft program also sustained itself post-war, with these large contracts (including the Curtiss XP-87) totaling 41 new aircraft of 20 individual types in 1946.[280]

As early as November 1945, however, the Army Air Forces had foreseen that future industrial preparedness would require actions beyond the implicit passive plan achieved through selected production contracts, return of aircraft plants to private industry, and mothballing unsold facilities. The Under Secretary of War approved the *Report on Demobilization of the Aircraft Industry* late that month, a document that laid out the premise of the post-war Air Materiel Command preparedness mission. The report emphasized the need for progressive R&D for aircraft and weapons; maintenance of a healthy aircraft industry; sustained aircraft industry readiness for volume production; and, "a reserve of standby plants, machine tools, and strategic materials." As the peacetime economy began to reassert itself in 1946, and as the Cold War simultaneously unfolded, the War Department's plan tightened

> based on the assumption of 'attack without warning' instead of on 'one year's warning.' Standby plants were not to be used for AAF storage but were to be leased to industry with certain restrictive provisions enabling their recapture in 60 days in the event of emergency. Greater emphasis was to be placed on tooling production. Preferential treatment of the aircraft industry was eliminated. And security planning was shifted from relocation of aircraft plants to the protection of plants in their existing location.[281]

Industrial mobilization was an Air Materiel Command mission that involved a sustained interaction with weapons systems manufacturers. Oversight and management of large, industrial plants—plants that would continue in use through additions and renovation, and new plants built during the Cold War era—became a major command responsibility. The earliest administration of industrial plants resided at Headquarters Air Materiel Command within the Logistics Planning Division of Plans (T-5), as an Industrial Plans section.[282] As 1946 opened, the Army Air Forces had jurisdiction over nine "standby plants." Each of these facilities was an aircraft or aircraft-components manufacturing site, with the total representing about 25 percent of the aircraft production plants built during World War II for the American military. In the Army Air Forces standby group were five GOCOs, including the Martin plant in Omaha, North American in Kansas City, Douglas in Tulsa, Consolidated-Vultee in Fort Worth, and Bell in Marietta. The RFC had acquired formal ownership of the other four plants: Boeing in Wichita, Allison in Indianapolis, Studebaker in South Bend, Indiana, and Wright in Lockland (Cincinnati), Ohio. Air Materiel Command, through its Air Installations Division, maintained the GOCOs, while the RFC managed the others. By mid-1946, federal policy authorized the leasing of the nine standby plants to private industry. As these nine plants represented the future industrial mobilization of the Army Air Forces (and subsequently, the Air Force), their use carried restrictions:

> (a) the government would retain recapture rights in the event of an emergency;
> (b) no major alterations could be made; and,
> (c) only the manufacture of objects similar to those made at the plant during the war would be permitted.

In addition, Army Air Forces policy forbade Air Materiel Command to use any of these nine plants as storage facilities. The command did not strictly adhere to this directive, however, with the interim use of the Douglas plant in Tulsa a prime example. Air Materiel Command likewise converted the

World War II Bell Aircraft plant in Marietta, Georgia, for storage of machinery and tools from 1945 to 1951. At this same time, the command's Air Installations Division initiated work toward a pilot underground aircraft manufacturing plant—that would become the project of J. Gordon Turnbull and would intimately involve the role of captured German engineers (see Volume I, Part III).[283]

During 1947 and 1948, industrial mobilization planning continued, with management within Air Materiel Command rising from the level of a section to that of a division. By late 1947, the Industrial Mobilization Planning Division was one of two under the Director, Procurement and Industrial Mobilization Planning, at Wright Field.[284] Air Force mobilization was also subsumed within parallel efforts of the Department of Defense through the newly created Munitions Board and through a sister civilian agency, the National Security Resources Board. (The latter agency replaced the War Production Board of World War II.) The Munitions Board's program allocating "private industrial capacity for procurement planning of the armed services" was known as Annex 47. As of January 1948, the Industrial Planning Division at Wright-Patterson had the responsibility for implementing Annex 47 at the Air Materiel Command level.[285] Planning within Annex 47 led to an Air Force assessment that industrial mobilization requirements to support the projected "70-group Air Force" would necessitate the availability of about 150 individual plants. Within the Air Force, Army, and Navy, Annex 47 industrial mobilization planning remained challenging. By 1949, the Munitions Board further defined Annex 47 to focus only on "the priority list of 271 corporations doing 62 per cent of the dollar volume of World War II business." The Air Force then revised its plant estimates to 159.[286] During 1948-1949, Air Materiel Command conducted plant surveys and meetings. The command evaluated the majority of the World War II corporations as offering an appropriate basis for the projected 159 Air Force plants.[287]

As was the case for the R&D half of Air Materiel Command during the late 1940s, the industrial plant program and the procurement mission strongly sustained a new post-war focus on the possibilities of theoretical science, experimental engineering, and improved manufacturing practices. During 1948, the Industrial Planning Division contracted a think tank, the Stanford Research Institute (SRI), to study the aircraft industry's long-term cycles and its need to achieve effective "expansibility" for the Air Force. SRI's submitted methodology offered Air Materiel Command "an important technique for maintaining a continuous appraisal and evaluation of the basic potential of the aircraft industry."[288] Sought-after industrial plants for Annex 47 included many that filled the comprehensive needs of making aircraft and weapons systems. Also addressed were plants that served a more R&D purpose. By late 1949, Air Materiel Command requested that the Aircraft Industries Association survey its membership to identify key manufacturing challenges that faced the industry. The association presented 196 industry problems that needed attention. The command responded by calling out those problems on which it would take action—again, illustrating the interwoven nature of industrial preparedness for future military mobilization that existed between the government and private sectors.[289]

One example of a plant adapted for Air Materiel Command R&D was a World War II aluminum extrusion facility in Adrian, Michigan (southwest of Detroit). The reactivated Adrian plant of late 1948 was a GOCO of very special type. The facility

> was to operate as a manufacturing methods plant open to private industry as a proving ground for new manufacturing methods concerned with national defense. ...The proposed plant was to operate as a direct aid to industry and in no way was to compete with industry, thus eliminating any possibility of a trend toward nationalization of the aircraft industry. Equipment housed there was

to be used solely to prove theoretical designs and was not in itself to be a source of manufacture.

Operations at Adrian were to Air Materiel Command's industrial plant program what installations like Eglin, Holloman, and Wendover were to the R&D half of the command at this same time. In addition, the plant offered a site for contractor testing too expensive to be underwritten by private industry—as would the AEDC in Tennessee by the middle 1950s. Paralleling other military R&D test locations of the late 1940s and early 1950s, the Adrian plant was to receive German equipment shipped from overseas as reparations. During the late 1940s at Adrian, Air Materiel Command planned to use foreign technology as a basis for developing new equipment, focused on the use of two German vertical hydraulic presses to manufacture wing spars and selected internal structural components of aircraft.[290] In communications between Headquarters Air Force and Air Materiel Command at Wright-Patterson, Air Force personnel discussed the Adrian plant as a key "manufacturing-processing" facility, further noting that its type should be considered the model for an "Uncle Slant George" [USG] project. Although the deciphering of "USG" is not yet determined (with Uncle Slant George merely a military alpha naming similar to "Able" and "Baker"), other self-contained references in the communications indicate that the USG project was a hardened, underground plant such as that in design by J. Gordon Turnbull for Air Materiel Command for the manufacture of aircraft engines[291] (see Volume I, Part III) and by Black & Veatch for the War Department / Sandia for nuclear weapons storage and maintenance (Manzano, Killeen, and Clarksville Bases).

A particular unit of industrial mobilization planning of the late 1940s was the standby plant. Management of standby plants under Air Materiel Command in 1946 foreshadowed wider Congressional action through the creation of the National Industrial Reserve during 1947 and 1948. The National Industrial Reserve Act of 1948 formalized the program. Initially, the National Industrial Reserve "consisted of government-owned plants that were not needed in peacetime and could be reconverted to civilian production, but which were considered essential to wartime production." Plants under the National Industrial Reserve were of two types: those of no national security value that could be sold without restrictions, and, those that could be sold, but only with the restrictions of a national security clause. The security covenants prevented modification of the plants and required their return to military use within 120 days in an emergency. Under the National Industrial Reserve, the selected GOCOs that could not be sold were to be held by the Federal Works Agency (and subsequently, the General Services Administration [GSA]). The National Industrial Reserve was subsumed within the Industrial Plant Reserve, the latter representing the full gamut of industrial facilities thought to be needed during a future war. The military service arms, including the Air Force, contributed to a Departmental Industrial Reserve that included aircraft plants, munitions plants, and shipyards. By the close of 1948, the Air Force plant program had grown from nine standby plants to 26 (not all GOCOs). Total standby plants within the National Industrial Reserve that year was 234, with 158 of these within the Departmental Industrial Reserve grouping of the Air Force, Army, and Navy. In counterpoint to the Air Force's 26 standby plants, the Army owned 48 such plants, the Navy 84.[292] Standby plants were the core infrastructure of the industrial plant program immediately post-World War II. As of 1955, the Departmental Industrial Reserve included 249 plants, while unsold plants in the National Industrial Reserve numbered 39.[293] Not surprisingly, perhaps, in 2002 the four sustained GOCO Air Force plants include two of the original nine of 1946: Air Force Plant (AFP) 4 in Fort Worth, Texas, and AFP 6 in Marietta, Georgia.

Field and plant representation was highly fluid within Air Materiel Command, with many changes during the late 1940s and steady augmentation into the early 1950s. In addition to managing the developing Cold War system of Air Force plants, the command maintained a procurement field organization of geographic offices concentrated by their associated industries. The field offices

managed industrial procurement contracts, and were sometimes physically located adjacent to the Air Force plants themselves. Duties within this network included "interpreting and insuring compliance with contractual provisions, inspection, production, follow-up, and industrial property accounting requirements." In mid-1948, for example, Air Materiel Command's procurement field organization administered 14,338 contracts. Where the work was of major significance, Air Force industrial plants also supported Air Materiel Command plant representatives on site.[294] Procurement Field Offices opened and closed, with Air Materiel Command plant representatives sometimes replaced by positions in procurement offices sited in regional proximity.

The overlapping nature of Procurement Field Offices and Air Force Plant Representative Offices (AFPROs) typically meant that within a single geographic region the Procurement Field Office would be physically located in one city, often in a non-Air Force facility such as the Post Office, while the AFPRO at a key plant might be hundreds of miles distant—or nearby. In the Air Materiel Command delineation of its westernmost procurement region in 1947, the Procurement Field Office was in Los Angeles, while an AFPRO existed for Boeing in Seattle. That same year, the command placed the Procurement Field Office for its south-central region in Dallas and its AFPRO for Consolidated-Vultee in Fort Worth. In 1948, Air Materiel Command combined its Dallas-Fort Worth offices into a single Procurement Field Office in Fort Worth, subsuming the former AFPRO for Consolidated-Vultee within it. Field procurement organization of the period implied that when both a Procurement Field Office and one or more AFPROs existed in one geographic region, the Procurement Field Office handled all contracts except those directly undertaken through AFPRO management. Later examples also indicate that sometimes an AFPRO oversaw more than one Air Force plant, configuring its contract duties instead by manufacturer. Such was the case for Allison in Indianapolis for AFP 26 and AFP 30 at the outset of the 1960s.[295]

In 1947, the command coordinated 10 Procurement Field Offices, trimming these to seven as of May (with an additional six suboffices). Eliminated were St. Louis, Cleveland, and Atlanta, with offices remaining in Boston, New York, Dayton, Detroit, Chicago, Fort Worth, and Los Angeles. The command assigned each office a geographic area similar to the regional system of the AMAs, although jurisdictions for procurement and those for supply-maintenance did not match[296] (Plates 40-41). The only likeness was the larger size of jurisdictions in the interior of the country. AFPROs also numbered seven in mid-1947: Boeing in Seattle, Consolidated-Vultee in Fort Worth, Allison in Indianapolis, Bell in Buffalo and Republic Aviation in Farmingdale (New York), Wright Aeronautical Corporation in Patterson (New Jersey), and Fairchild in Hagerstown (Maryland). By 1949, Air Materiel Command maintained six AFPROs instead of seven, with one added at the Boeing plant in Wichita, Kansas, and those of Bell in Buffalo and Consolidated-Vultee in Fort Worth subsumed within the Procurement Field Office network. Change would continue to be the norm. In early 1953, assigned geographic areas for the Procurement Field Offices were those of the Northeastern, Eastern, Central, Midcentral, Southern, and Western Air Procurement Districts, with the district previously managed through the Dayton office eliminated.[297] (Air Materiel Command focused on production issues in its Procurement Field Office and AFPRO network. Plant real estate and facilities management was also regionalized, but fell to the command's depots through the 1950s and thereafter to Aeronautical Systems Division—subsequently, ASC—at Wright-Patterson.)

Cataloguing Air Force industrial plants, either by name or number, also evolved over time. Air Materiel Command first numbered its GOCO plants during 1946-1947, referring to them as Government Aircraft Plants (GAPs) as of this date. From the first, the situation was confusing. A numbered ordering of World War II plants had not occurred, and further complicating matters, the government did not correlate GAP designations after the war to a World War II construction-date for reused plants. The GAP numbering included *all* government-owned aircraft plants under the National Industrial Reserve program, and thus represented facilities that were Air Force, Army, and Navy. As

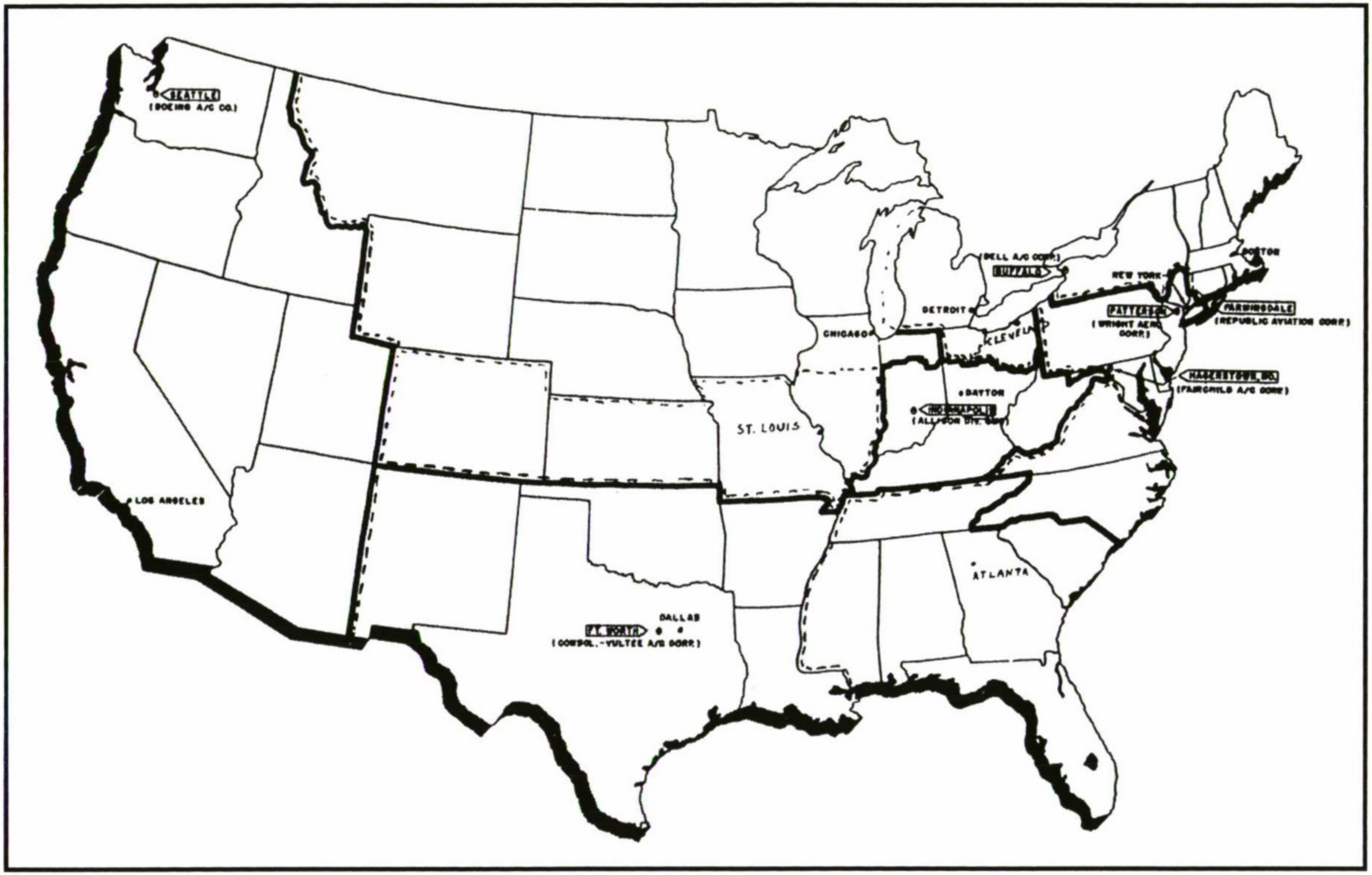

Plate 40: **Air Materiel Command, Army Air Forces Procurement Field Offices, Procurement Areas, and Industrial Plant Representatives, April-May 1947. Dotted lines denote the procurement area boundaries before April 1947, while the solid lines mark those after mid-May. In *History of the Air Materiel Command 1947*, volume 2.**

Plate 41: **Air Materiel Command, Air Force Procurement Field Offices and Boundaries Map, 15 March 1948. Adapted from *History of the Air Materiel Command 1 July – 31 December 1949*, volume 2.**

a result, the Air Force industrial plants managed under Air Materiel Command were not consecutive in their numbering. Early "skips" indicated plants managed by either the Army or Navy, or, by other Air Force commands. GAP numbering, too, quickly included plants either permanently removed from the system (and thus creating yet another kind of hole in the numbering) or plants transferred away from Air Materiel Command, but maintained as GOCOs for the military. GAP No. 1, the Martin B-26 bomber plant designed by Albert Kahn in 1941 (see Plate 38), stayed within Air Materiel Command jurisdiction only briefly and never returned. Between April 1946 and about 1949, the plant was an Air Force standby plant.[298] The manufacturing facility then passed to SAC and out of assembly plant status. The "A Building," a small office structure interconnected to the Martin plant in Omaha, served as the first headquarters for SAC (and as Curtis LeMay's office) at Offutt Air Force Base from 1948-1949 into 1957.[299] During 1949, the Air Force transferred GAP No. 2, the aircraft assembly plant in Kansas City, from management under the Oklahoma City AMA (of Air Materiel Command) to Continental Air Command.[300] Standby plants under Air Materiel Command's umbrella during 1948-1949 were GAP No. 1 in Omaha, GAP No. 3 in Tulsa, GAP No. 6 in Marietta, and GAP No. 7 in Cleveland. GAP No. 4, the Consolidated-Vultee plant in Fort Worth, was not under Air Materiel Command jurisdiction through mid-1949—although the plant functioned as a GOCO and later would return to the command as AFP 4. (GAP No. 4 manufactured the B-36, but SAC may have had jurisdiction.)[301]

Later in time, GAP designations shifted to AFPs within Air Materiel Command / AFLC, and subsequently AFSC. The GAP numbering of 1946-1947 appears to have carried forward unchanged as AFP numbering, as long as the facility was a continuous GOCO under the command. (The GAP program used "No." in its system, while the most recent version of the AFP program does not: hence, GAP No. 6 becomes AFP 6 today.) Complexity of plant usage and management over the decades suggests a cautious evaluation of lineage. The historic continuity of the GAP-AFP numbering system internal to Air Materiel Command / AFLC, beginning with No. 1, break downs as of about No. 60—although this assessment is only tentative. AFP 60 further serves as an illustrative example of the complexity of numbering, ownership, and tracking issues. AFSC listed the facility as the Bridgeport Brass Company in Adrian, Michigan, in a 1976 compendium of plants removed from Air Force inventory. AFP 60 is very likely a reuse of the manufacturers' proving ground plant of the late 1940s (originally erected as an aluminum extrusion plant during World War II). AFSC lists "1953" as the date that the Air Force "acquired" and numbered the plant as AFP 60. The Adrian plant almost certainly began as a lower numbered facility, which moved into private-sector ownership sometime between the late 1940s and 1953. Further research indicates that AFP 60 became the responsibility of the Mobile AMA at Brookley in March 1956 and next came under the jurisdiction of Wright-Patterson. In early 1959, the Bridgeport Brass Company in Adrian sustained a special mission handling and producing large quantities of radioactive materials as a subcontractor to National Lead of Ohio (NLO) at its Fernald plant near Cincinnati. NLO converted uranium into fuel elements for production reactors and processed depleted uranium (DU) for munitions and armor.[302] By May 1959, AFLC had declared AFP 60 excess. In mid-October 1961, the Air Force sold the Adrian plant to the Harvey Aluminum Company of Torrance, California. Yet, in the transfer of industrial facilities from AFLC to AFSC (see below) during the previous month, the Adrian plant is nonexistent as a numbered or named facility—presumably due to its excess status.[303]

Many changes also occurred tied to the general shrinking of the industrial plant program across the Air Force, Navy, and Army. Higher-number AFPs, from AFP 60 through AFP 85, also include plants that were once Departmental Reserve facilities for other military arms. One example is AFP 85 in Columbus, Ohio, a facility that functioned continuously as a standby plant for the Navy after 1950 until acquired as a GOCO by AFSC in 1982. In the case of Columbus, the likelihood is that an original GAP number existed under Navy jurisdiction, a number discontinued with the transfer to AFSC. Another example of the effects of the changing size of the overall program is AFP 70 in

Sacramento (Folsom). In that instance, the Air Force had acquired the plant as a GOCO in 1957, after private construction of the facility earlier in the decade. AFSC excessed the plant during 1969-1972, with AFLC at McClellan then responsible for its real property. The command formally transferred AFP 70 to an AFLC military account as of 1973. In mid-1974, AFSC listed the original private-sector contractor, Aerojet, as still owning facilities at the location for work on Titan and Minuteman ICBMs under Aeronautical Systems Division at Wright-Patterson. The Air Force owned equipment within Aerojet's plant. AFSC next reacquired AFP 70 from AFLC for Minuteman testing in 1975. In 1982, AFP 70 became a GOCO for the MX (missile experiment) Peacekeeper—although AFSC first attempted to sell AFP 70 to Aerojet, rather than operate the facility as a GOCO. Aerojet and Air Force ownership of facilities and equipment at this Sacramento plant was highly interwoven over time. While the AFP 70 designation may or may not be its first numbering, the plant has a fluid lineage regardless.[304] One can also find other industrial standby plants of the armed services on current installations within Air Force Materiel Command—further masking the entire industrial mobilization effort of the early Cold War. An example is the Douglas Aircraft standby plant for manufacture of the A-4D Skyhawk, established in 1954 as a Navy Industrial Reserve facility in Los Angeles. The Douglas plant augmented a preexisting World War II plant of North American Aviation on site, with property apparently split up between the companies after the war. Today, several of the Douglas plant buildings physically function as warehouses at Los Angeles Air Force Base (see Volume II, Chapter 9).

While the Air Force separated R&D from Air Materiel Command's procurement and logistics functions at the outset of 1950, the event most affecting the Air Force industrial plant program and the procurement mission was the outbreak of the Korean War at mid-year. Preparations for industrial mobilization were not yet solid by this date, and for various reasons the kind of preparations made by the Munitions Board and its civilian counterpart were also not a particularly good fit for the military emergency. When envisioned in 1946-1948, the industrial mobilization effort assumed that the next war would be like World War II in its all-encompassing scope—with the addition of more deadly weapons. Korea was a limited war in Asia. And although it did represent exactly the kind of situation that George Kennan had predicted in his 1947 essay defining the Cold War, Korea caught the industrial preparedness program before it was ready. Korea demanded a much quicker mobilization than had World War II, for what was anticipated to be a short war. The Korean War lasted longer than assumed, yet never included the full turnover of civilian industry to the war effort. President Truman did not want the economy to be disrupted so soon after its recovery from depression and World War II. Truman's position on the issue consequently forced defense-allocated industry to compete with civilian industry for its resources and personnel.

In addition, each of the service arms discovered that more time was required than had been planned to activate mothballed plants and to realign others for wartime needs. Nonetheless, Air Materiel Command did get its plants on line, expanding certain facilities and adding others. Acquired plants generally did not represent new construction, but rather renovation and supply of equipment to existing, vacant World War II facilities. Private industry remained cautious about investment in the war enterprise, with memories of the very lean years following World War II too fresh to set aside. With healthy financial incentives, however, industry did participate. The government owned 288 plants at the end of the war, with most held in the military's Departmental Industrial Reserve. Aircraft plants increased to 47 as of mid-1954. Fully 41 of these plants were in active contractor use as GOCOs, or were leased to industry.[305] As of October 1953, Air Materiel Command had organized oversight of procurement contracts and industrial plants through its six Procurement Field Offices, supported through 24 regional offices and with 36 AFPROs at the largest contractor sites.[306]

After the Korean War, the American military did not demobilize in a manner similar to all previous wars. From this point forward, the Cold War defined new needs, with a much higher sustained

readiness of immediate consequence. The elevated science of the period, with technological progress racing into the future, also kept all parts of the Air Force actively current. Air Force GOCOs came to include much more than the traditional aircraft production, components, and weapons plants. Just as was true for ARDC and the supply / maintenance mission, the rapid growth of the ballistic missile program, in particular, created a requirement for wholly new Air Force industrial plants—plants to be built from scratch or ones that at most would reuse existing World War II airfields. Where possible of course, the Air Force adapted a World War II aircraft production plant for missiles production. Such sites included AFP 19 in San Diego adjacent to Montgomery Airfield. In 1956-1957, Air Materiel Command adapted the plant from B-24 production for work on the Atlas missile.[307] During 1941-1945, the San Diego Consolidated Aircraft plant had functioned as a GOCO. The government had declared the facilities surplus in 1946, subsequently selling them to private industry. Air Materiel Command reacquired the plant in 1957.[308] The conversion to missile manufacturing reused the 500,000 square-foot single-story aircraft factory, but the command added two six-story office buildings and two complexes of open-courtyard ("waffle pattern") engineering laboratories on site.[309] Convair also supported its work at the plant with an Atlas test stand complex at Point Loma, and, two captive test stands in Sycamore Canyon, erected in 1956 and 1959.[310] North American Aviation, too, erected test stands for Atlas single booster engines in 1955, in Santa Susana Canyon northeast of Los Angeles (Plate 42).

For these plants, the Air Force often combined the GOCO system with facilities fully owned and operated by the contractor, with one major example the 1956 Titan ICBM plant of the Glenn L. Martin Company (later, Martin Marietta) near Denver (also known as AFP PJKS) (Plate 43).[311] In other cases, such as AFP 44 built in Tucson to manufacture the Falcon guided missile in 1951, the private company with the government systems contract (here, Hughes Aircraft) fully financed erection of the plant. Subsequently, early in the plant's operation, the Air Force purchased the facility and operated it thereafter as a GOCO. Aerojet's AFP 70 is another such example, as discussed above.[312] Even at traditional aircraft production facilities, new ideas replaced the 1946 plan to retain plants without alteration until mobilization so required. The Air Force added state-of-the-art equipment; improved and lengthened runways; and, oversaw expansion at existing building complexes.[313] At the close of 1958, the Air Force oversaw 80 plants, with all but five of these in active production.[314] Shortly after this date, Air Force industrial plants peaked in numbers at just over 90.[315] The middle-to-late 1950s, generally, represented the pinnacle of federally-owned and affiliated industrial plant endeavors across the services.[316]

The majority of oversight and ownership of Air Force industrial plants, or portions of these plants, transferred from AFLC to AFSC in July 1961. The change immediately followed the redesignation of ARDC as AFSC, and of Air Materiel Command as AFLC the previous April. AFSC sources indicate a total of about 74 active Air Force industrial plants in 1961.[317] While this figure did not include plants already declared excess, but still owned by the Air Force (such as AFP 60 in Adrian, Michigan), it does provide a good benchmark for the relative number of plants left under AFLC management. The Headquarters AFLC Special Orders of September 1961 listed 67 plants transferred to AFSC in July, suggesting that about seven remained under AFLC control.[318] A steady divestiture of plants had begun in 1960, with the numbers of plants dropping each year. Plants were down to 70 in 1964; to 60 in 1966; to just over 50 in 1968; and, to just over 35 in 1973 (Plate 44).[319] Overall, government-owned industrial plants declined in numbers from 261 in 1960, to 216 in 1966, with investments focused instead on the purchase of operating equipment. By the middle 1970s, AFSC managed 27 plants with varying percentages of GOCO status. While the total number of active plants had peaked at 90+ toward the end of the 1950s, the Air Force actually disposed of 80 plants between 1958 and 1976—indicating that a small number of new or reacquired plants came on line as the overall numbers diminished. AFLC maintained no GOCOs by 1976, but did have facilities contracts for mixed private-sector and government use at about a dozen locations.[320]

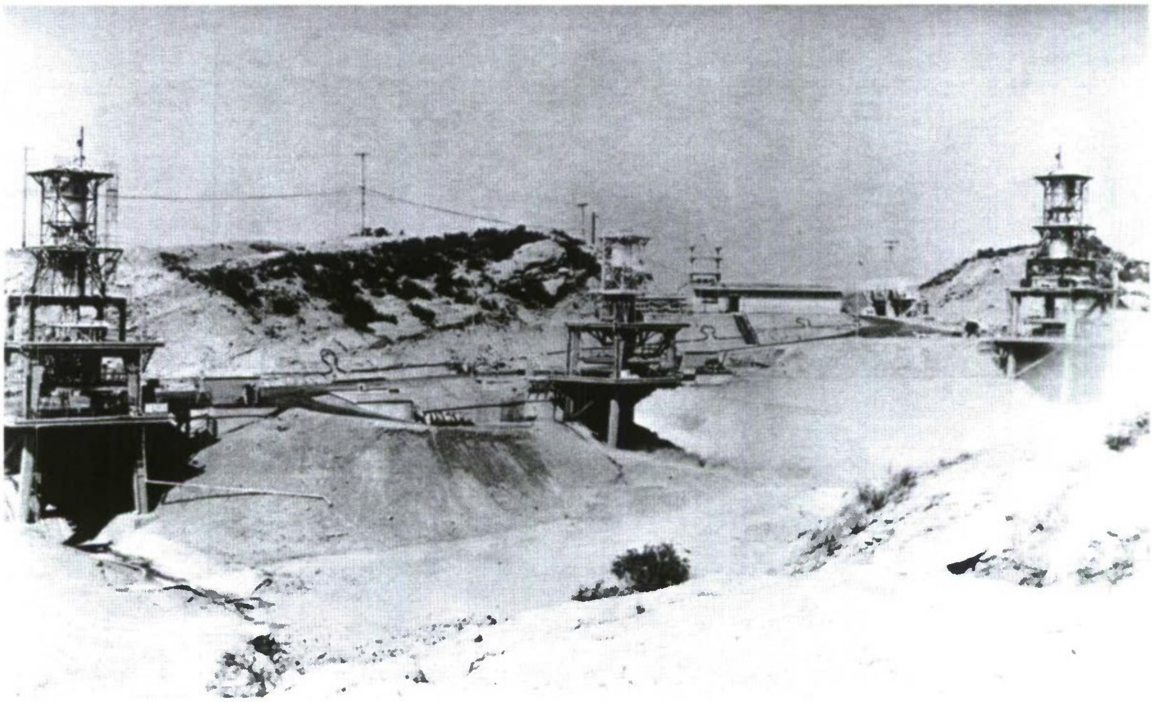

Plate 42: North American Aviation Test Site, Santa Susana Canyon, California. Firing of an Atlas single booster engine. In *History of Air Research and Development Command 1 July – 31 December 1955*, volume 1.

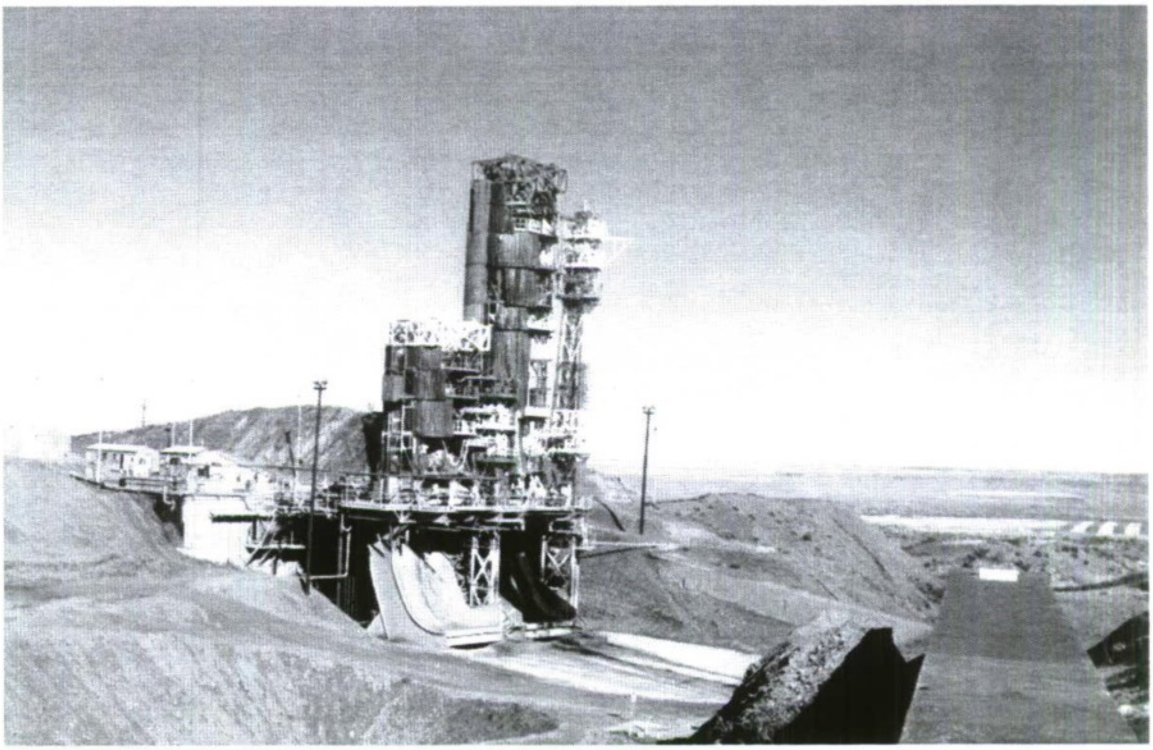

Plate 43: Ralph M. Parsons. Titan test stand, Martin Marietta Titan Plant (AFP PJKS), Denver vicinity, 1956-1958. Courtesy of Joseph Trnka.

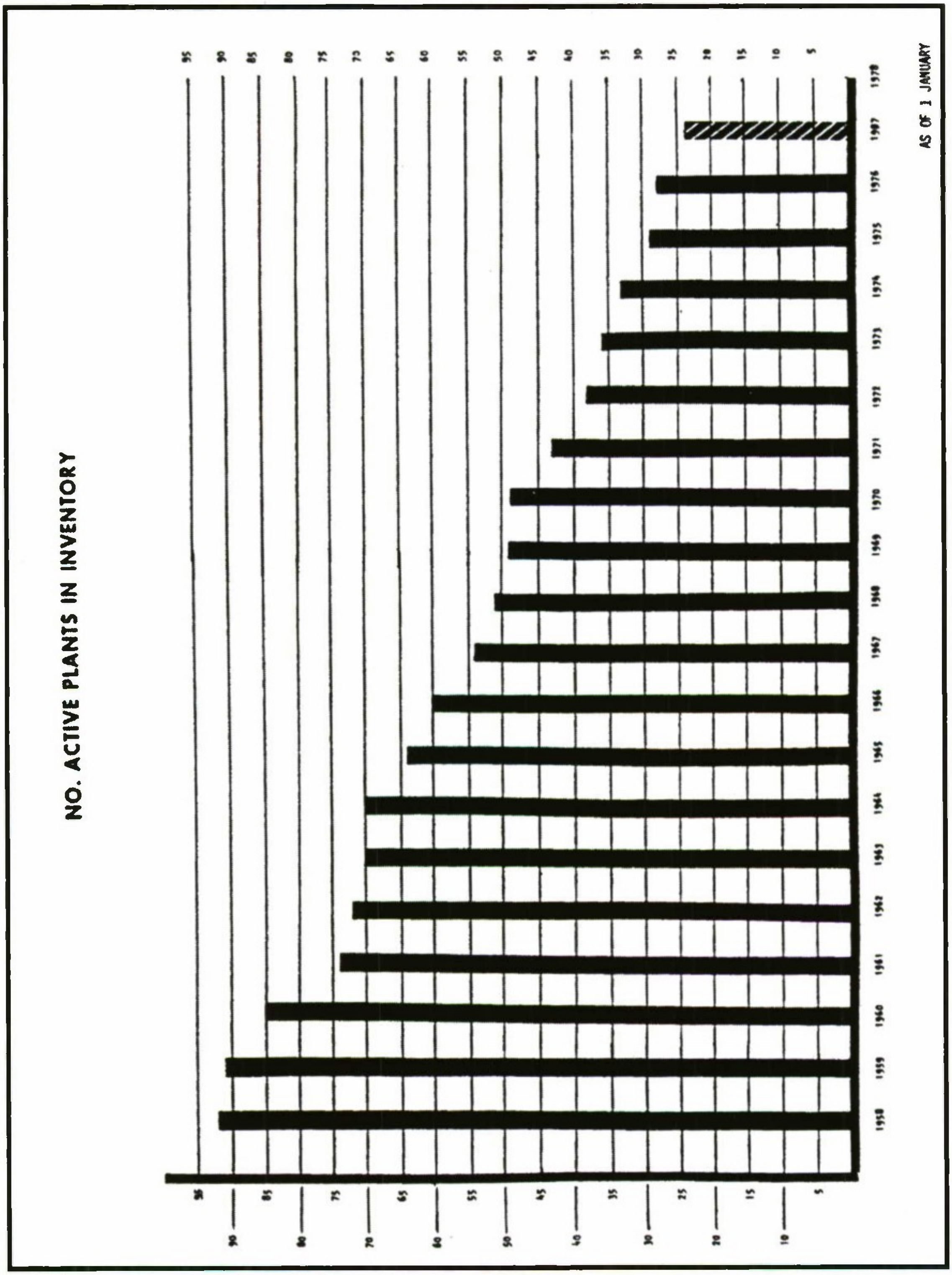

Plate 44: Active Industrial Plants in Air Force Inventory, January 1976. In *Facilities Contracts Leases Industrial Management Report*, 1976. Courtesy of Frank Tokarsky.

The disposal of industrial plants that were no longer needed was a complex process from the late 1950s forward. Within the Air Force, government-owned plants became excess as contracts concluded at particular locations. These transferred to the National Industrial Reserve. Federal policy for government-owned industrial plants required that Air Materiel Command, and subsequently AFLC and AFSC, dispose of excess properties if no other government agencies required the facilities. Defense Mobilization Order-VII-7 of March 1957 had added further guidance for the retention of a mobilization base, requiring idle plants to go through annual update reviews.[321] By definition, in 1958, excess Air Force plants with security covenants were ones for which the Air Force legally retained "the availability of their productive capacities in order to contend with emergencies." The Army Corps of Engineers acted as the real estate agency for excess Air Force industrial plants, in turn passing the responsibility for negotiating the sale of excess plants to the GSA. At the outset of the 1960s, the GSA had one year to sell such plants for the Air Force, while the Air Force provided the funding for their continued maintenance. After a year, the GSA took over custodial costs and Air Materiel Command / AFSC sustained the plants' service contracts. Key challenges for quick sales were the restrictions that the Air Force imposed:

- the buyer was to "maintain equivalent productive capacity [at the plant] for Air Force use;"
- price was set at current fair market value [often too high to facility sale with restrictions];
- the Senate and House of Representatives Armed Services Committees must concur with all sales;
- the Justice Department additionally cleared all industrial plants valued above one million dollars; and,
- reports of negotiated sales went before the Government Operations Committees of both the Senate and House.

Maintenance of plants that had become idle, but not yet excess, was another costly issue. To reduce maintenance costs during a protracted process, the Air Force considered leasing facilities, or parts of facilities, to private contractors, but this strategy was poorly received by GSA. In many cases, the process took years.[322]

AFSC catalogued most of its industrial plants with a number and an alpha designation.[323] In 1976, the 27 plants were:

- AFP 3 (Tulsa);
- AFP 4 (Fort Worth);
- AFP 6 (Marietta);
- AFP 13 (Wichita);
- AFP 19 (San Diego);
- AFP 27 (Toledo);
- AFP 28 (Everett, Massachusetts);
- AFP 29 (Lynn, Massachusetts);
- AFP 36 (Evendale [greater Cincinnati]);
- AFP 38 (Binghamton, New York);
- AFP 42 (Palmdale, California);
- AFP 43 (Stratford, Connecticut);
- AFP 44 (Tucson);
- AFP 47 (Cleveland);
- AFP 49 (Buffalo);
- AFP 50 (Halethorpe, Maryland);
- AFP 59 (Binghamton, New York);

- AFP 63 (North Grafton, Massachusetts);
- AFP 65 (Neosho, Missouri);
- AFP 77 (Hill Air Force Base, Utah);
- AFP 78 (Brigham City, Utah);
- AFP 80 (Saltville, Virginia);
- AFP 83 (Albuquerque);
- AFP 84 (St. Louis);

as well as the three unnumbered plants of:

- PGTS (greater Los Angeles);
- PJKS (greater Denver); and,
- GCBD (St. Louis).[324]

Twelve of these plants were in active or planned disposal by the late 1970s (AFP 3, 19, 28, 29, 36, 43, 65, 78, 80, 83, PGTS, and GCBD).[325]

The Vietnam War also affected the Air Force plant program, although not in ways wartime production might have been anticipated to shape industrial mobilization. While ammunition plants for the Army radically increased from standby to active status during 1965-1969,[326] Air Force plants merely stabilized during 1963-1964 before resuming a decline in numbers.[327] Generally speaking, the role of Air Force plants in the Vietnam War came earlier than those of the Army—with Air Force involvement as of 1961 (refurbishing and modifying World War II aircraft). After 1969, and certainly after a Department of Defense directive of early 1970, government ownership of industrial facilities was less and less encouraged.[328] Policy favored maximum reliance upon the private sector to provide its own industrial facilities.[329] During the later 1970s through the 1980s, the number of Air Force industrial plants continued to shrink. An Air Force desire to sell some plants remained problematic, due to lack of agreement between the agency and the prospective contractor-buyer.[330] Nonetheless, the Air Force sold many plants to private industry throughout the post-1960 period, with several dismantled and handled as scrap. The Air Force also transferred a significant number of industrial plants to sister military and civilian agencies, including the Army, Navy, NASA, and AEC. A few plants moved under the jurisdiction of universities such as the Illinois Institute of Technology (IIT) in Chicago.[331]

At the height of the Reagan presidency in 1986, AFSC managed 13 GOCO plants, with 12 in active status and one mothballed. Active plants were those of AFP 3, 4, 6, 19, 36, 42, 44, 59, 70, 78, 85, and PJKS. AFP 38 in upstate New York was in inactive status in 1986, with its final programs those of Minuteman production in 1981 and laser research projects in 1983. Industrial plant activities of the late Cold War focused on sophisticated aircraft and missiles. Sustained and new aircraft programs at the end of the war included:

- the AV-8 at AFP 3;
- the B-1 at AFP 3, 42, 59, and 85;
- the F-5 at AFP 42 an 59;
- the F-15 at AFP 3 and 59;
- the F-16 at AFP 4;
- the F-18 at AFP 3 and 59;
- the F-101 at AFP 36;
- the F-110 (F-4) at AFP 36;

- the F-111 at AFP 4;
- the C-5 at AFP 6 and 59;
- the C-130 at AFP 6;
- the C-141 at AFP 6;
- the SR-71 at AFP 42;
- the TF39 (turbofan engine for the C-5) at AFP 36;
- the TR-1 at AFP 42; and,
- the U-2 at AFP 42;

while missiles and space launch programs of the middle 1980s were those of:

- the Atlas ICBM modified as a booster vehicle at AFP 19;
- the Titan ICBM modified as a booster vehicle at AFP 70 and PKJS;
- the Centaur upper-stage vehicle at AFP 19;
- the Air-to-Ground Missile [AGM]-65 (the Maverick) at AFP 44;
- the Air Intercept Missile [AIM]-54 (the Phoenix) at AFP 44;
- the AIM-120 (Advanced Medium Range Air-to-Air Missile [AMRAAM]) at AFP 44;
- the Ground-Launched Cruise Missile (GLCM) at AFP 19;
- the MX Peacekeeper ICBM at AFP 70, 78, 85, and PKJS;
- the Trident sea [submarine]-launched ballistic missile (SLBM) at AFP 78; and,
- the Tube-launched, Optically-tracked, Wire-guided (TOW) missile at AFP 44.

Several plants were responsible for multiple programs. Particular plants were especially complex in their operations, including AFP 42 and 44. At AFP 42, in Palmdale, California, multiple contractors managed separate numbered areas within the overall plant, thus partially accounting for the number of high-profile projects in progress during 1986. AFP 42's proximity and interrelationship with the Air Force Flight Test Center at nearby Edwards Air Force Base was also a major factor. In the middle 1980s, the Air Force Industrial Plant Ownership and Disposal Plan recommended that AFSC keep seven of the 13 plants and dispose of the remainder. Projected keepers were AFP 3, 4, 6, 19, 42, 44, and 85. AFSC evaluated its acquisition cost for the 13 plants as $695 million over preceding 40 years, with an estimated replacement value of $3.4 billion. In terms of fixed assets, AFSC GOCO facilities ranked 45th in the Fortune 500 listing of corporations in the United States.[332]

As a part of the Strategic Arms Reduction Treaty (START) of July 1991 between the United States and the Soviet Union, several Air Force industrial plants became bargaining chips. A Memorandum of Understanding (MOU) tied to START, a critical tool bringing the nearly 50-year war to its conclusion, required inspection of five types of military sites within both nations. Inspections included three types: on-site inspections, suspect-site inspections, and elimination-site inspections. Suspect-site inspections applied to "production facilities which were capable of producing items prohibited or accountable under the treaty to verify compliance." Within AFSC at the close of the war, the START MOU identified one industrial plant as a suspect site: AFP 70 in Sacramento. AFP 70, an Aerojet facility of the early 1950s, tested rocket motors for missile systems, including the Minuteman and Peacekeeper. During the lifespan of AFP 70, the plant had also manufactured missile components. Also subject to treaty compliance was AFP 78 in Brigham City, Utah, near Hill Air Force Base. AFP 78, a Thiokol facility, was partially government-owned, yet highly integrated with private industry. Built during 1957-1962, APF 78 fell under another START provision for perimeter portal continuous monitoring. The monitoring was to certify that the facility did not produce "treaty limited items" (of which it was capable).[333] Thiokol made rocket motors for Minuteman, MX Peacekeeper, and Trident II.[334]

As of 2000-2001, AFMC was continuing to simplify the organization of the Air Force industrial plant structure. At the close of 1999, 11 plants remained on line: AFP 3 in Tulsa, AFP 4 in Fort Worth, AFP 6 in Marietta, AFP 19 in San Diego, AFP 42 in Palmdale, AFP 44 in Tucson, AFP 59 in the vicinity of Binghamton, AFP 70 in the vicinity of Sacramento, AFP 78 in Brigham City, AFP 85 in Columbus, and AFP PJKS in the vicinity of Denver. Of these plants, four were missile plants and seven, aircraft production. By the turn of FY 2000, AFMC had sold or transferred four of the 11 remaining plants: AFP 19, 70, 78, and 85. Of these, two were originally World War II aircraft production plants. AFP 19 was a GOCO of 1940-1941 that had manufactured bombers, converted for manufacturing the Atlas ICBM in the late 1950s. AFP 85 of 1941 had produced Navy aircraft and served as a Navy standby plant as of 1950. The Air Force did not acquire AFP 85, a very early plant with a late number, until 1982.[335] AFP 70 and 78 were both missile facilities of the late 1950s and early 1960s. AFSC closed these two plants after fulfilling obligations under START. During FY 2000, AFMC transferred title of AFP 3 (originally built as a World War II aircraft plant) to the City of Tulsa. The situation for AFP 59 (originally, a World War II propeller plant) remains pending. The Air Force and the Broome County Development Authority have signed a divestiture agreement, with the final sale of the plant on hold until resolution of environmental remediation issues.[336] Currently, AFMC is in the final stages of selling AFP PJKS, the Titan missile plant in Denver, to bring the post-Cold War industrial plant program to four "super" plants: AFP 4, 6, 42, and 44 in Fort Worth, Marietta, Palmdale, and Tucson, respectively. The four plants are spread across the southern United States, with a concentration in the West.[337] Two of these plants date to the early 1940s (Fort Worth and Marietta), with their numbering directly evolved from GAP No. 4 (AFP 4) and GAP No. 6 (AFP 6). The other two date to 1951 (with Palmdale also a World War II airfield).

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[1] Michael H. Gorn, *Vulcan's Forge: The Making of An Air Force Command for Weapons Acquisition (1950-1985)*, volume 1 (Andrews Air Force Base: Office of History, Air Force Systems Command, second printing, October 1986), xiii-xiv.

[2] Karen J. Weitze, *Aeromedical Evacuation Annotated Bibliography* (Colton, California: Earth Tech, Inc., for the United States Air Force Center for Environmental Excellence, November 1994), 1-8 and 11-5.

[3] Emma J.H. Dyson, Dean A. Herrin, and Amy E. Slaton, *The Engineering of Flight: Aeronautical Engineering Facilities of Area B, Wright-Patterson Air Force Base, Ohio* (Washington, D.C.: Historic American Buildings Survey (HABS) / Historic American Engineering Record (HAER) of the National Park Service, 1993), 2-5; Gorn, *Vulcan's Forge*, volume 1, 1986, xiii.

[4] James F. Aldridge, Dean C. Kallander, Paul C. Ferguson, Laura N. Romesburg, and Henry M. Narducci, *Against the Wind: 90 Years of Flight Test in the Miami Valley* (Wright-Patterson Air Force Base: History Office, Aeronautical Systems Center, Air Force Materiel Command, 1994), 4-6.

[5] Henry M. Narducci, *A Century of Growth: The Evolution of Wright-Patterson Air Force Base* (Wright-Patterson Air Force Base: 88th Air Base Wing, Aeronautical Systems Center, Air Force Materiel Command, August 1999), 3.

[6] Dyson, Herrin, and Slaton, *The Engineering of Flight*, 1993, 4-5.

[7] Narducci, *A Century of Growth*, 1999, 7-8.

[8] Charles G. Hibbard, Office of History, Ogden Air Logistics Center, Hill Air Force Base, "Closure of Air Materiel Areas and Air Force Depots," 17 November 1986.

[9] *Ibid*; Air Technical Service Command, *History of the Army Air Forces Air Service Command 1921-1944*, August 1945, 7-17.

[10] Gorn, *Vulcan's Forge*, volume 1, 1986, xiv.

[11] Karen J. Weitze and Christy Dolan, *Historic American Buildings Survey for the Marine Corps Air Station, Tustin, Lighter-than-Air Ship Hangars* (San Diego: KEA Environmental, Inc., for the Southwest Division, Naval Facilities Engineering Command, United States Navy, January 2000), 9; Christopher Dean (ed.), *Housing the Airship* (London: The Architectural Association, 1989); "Biographical Sketch of Dr. Arnstein," posted at www.uakron.edu/archival/arnstein/arnbio.htm.

[12] Aktien Gesellschaft is the German term for joint-stock company, similar to the American usage of "Incorporated." Dykerhoff & Widmann A.G. was alternately known as Dywidag, and Z-D also frequently appeared as ZD in referencing the construction technology.

[13] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 24-28; "Wartime Lessons for Peacetime Building: These War Buildings were Significant," *Engineering News-Record* 133, 16 (19 October 1944): 109-118; "Airfield and Hangar Structures by Roberts and Schaefer," jobs list in the Tedesko Archives, Department of Civil Engineering, Princeton University.
[14] In *Engineering News-Record*: "Large Concrete Warehouses Built with Moving Falsework," 126, 17 (24 April 1941): 52-54; "Quarter-Mile Long Army Warehouse Built in 36 Days," 127, 11 (11 September 1941): 65; and, "Mile of Concrete Army Depots Built in Record Time," 127, 19 (6 November 1941): 99.
[15] German engineers and architects led the world in structural and design innovations during the 1920s and 1930s. On the eve of World War II, and beginning as early as the 1910s, a number of German professionals migrated to England and the United States. The group was of a caliber unlike any then existing in non-German countries. In the United States, the exodus peaked in the early 1940s, with the War Department directly availing itself of selected men for classified design efforts. Of peripheral note, the teaching of both art and architectural history at the advanced university level in the United States dates to this period, with German professors uniformly heading art history departments and with the (American) Society of Architectural Historians founded in 1941.
[16] "Space Tower Near Completion," *The Marshall Star* 1, 20 (15 February 1961): 7.
[17] Ivan M. Viest, "Anton Tedesko 1903-1994," *National Academy of Engineering Memorial Tributes*, volume 8 (Washington, D.C.: National Academy Press, 1996), 262-267; Charles D. Benson and William Barnaby Faherty, "URSAM Makes Its Debut," *Moonport: A History of Apollo Launch Facilities and Operations*, NASA Special Publication 4204 in the NASA History Series, 1978, posted at www.hq.nasa.gov/office/pao/History/SP-4204.
[18] Narducci, *A Century of Growth*, 1999, 9-11.
[19] Dyson, Herrin, and Slaton, *The Engineering of Flight*, 1993, 6-24; Narducci, *A Century of Growth*, 1999, 12-16; Aldridge, Kallander, Ferguson, Romesburg, and Narducci, *Against the Wind*, 1994, 14-15.
[20] *Air Service Command 1921-1944*, 59-60, 79-80, 110-116, 137-139.
[21] Narducci, *A Century of Growth*, 1999, 17-23.
[22] *Air Service Command 1921-1944*, "exhibit 9" between 138 and 139.
[23] Hibbard, "Closure of Air Materiel Areas and Air Force Depots," 1986; *Air Service Command 1921-1944*, 113.
[24] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 1-2, 87-90.
[25] Julie L. Webster, Michael A. Pedrotty, and Aaron R. Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars (Draft): A General History, Thematic Typology, and Inventory of Aircraft Hangars and Associated Buildings on Department of Defense Installations* (Champaign, Illinois: United States Army Corps of Engineers Construction Engineering Research Laboratories, March 1996), 106-108. This document has gone final and is posted on the internet. The author, however, maintains and references the draft version.
[26] Air Depot Architect Engineers was a wartime collaboration of three New York firms, Alfred Easton Poor, Gibbs & Hill, and, Fred N. Severud. See, "Air Depot—Rome, N.Y.," *Engineering News-Record* 127, 5 (31 July 1941): 34.
[27] The author has field-checked the hangars at Eglin and Travis, although has reliable sources for the "Expandable Hangar" at Norton. Total number of these hangars, discovered to date, is four. See: Byrne Doors, Inc., letter to L.B. McCloud, Chief, Construction Branch, Army Air Forces, 19 July 1948, in File "Hangars 1948," Box 6, Entry 494, Record Group 341, National Archives II [verifying one hangar at Travis]; and, Webster, Pedrotty, and Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars (Draft)*, 1996, 109 and a drawing in Appendix B [verifying two hangars at Norton].
[28] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 99-104.
[29] Dyson, Herrin, and Slaton, *The Engineering of Flight*, 1993, 26, 186-191.
[30] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 87-97.
[31] Joseph Trnka and William Manley, *Historic Building Inventory and Evaluation Air Force Plant 4 Fort Worth, Texas* (Colton, California: Earth Tech, Inc., and William Manley Consulting, for the Aeronautical Systems Center, Air Force Materiel Command, January 1997), 3-21 to 3-28, with reproduced original drawings and plans.
[32] Aldridge, Kallander, Ferguson, Romesburg, and Narducci, *Against the Wind*, 1994, 17.

[33] Lenore Fine and Jesse A. Remington, *The Corps of Engineers: Construction in the United States*, unnumbered volume in *United States Army in World War II: The Technical Series* (Washington, D.C.: Office of the Chief of Military History, United States Army, 1972), 644-647.
[34] Dyson, Herrin, and Slaton, *The Engineering of Flight*, 1993, 26, 186.
[35] Trnka and Manley, *Air Force Plant 4 Fort Worth, Texas*, 1997, 3-26.
[36] Fine and Remington, *The Corps of Engineers: Construction in the United States*, 1972, 649.
[37] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 97-99.
[38] Army Air Forces Technical Base, *Preliminary Master Plan Report*, 18 March 1947, 15-18.
[39] *Ibid*; Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 93-94.
[40] Irving R. Friend, *History of the Air Technical Service Command 1945* (Wright-Patterson Air Force Base: History Office, Air Materiel Command, August 1950), 11-18.
[41] *Ibid*, 23.
[42] *Ibid*, 66.
[43] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 80-87.
[44] *History of the Air Technical Service Command 1945*, 67-68.
[45] Thomas W. Thompson, "Rome Laboratory: A Brief History," posted at www.if.afrl.af.mil.
[46] Air Technical Service Command, *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 3.
[47] *History of the Air Technical Service Command 1945*, 68.
[48] *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 2.
[49] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 56-77.
[50] *History of the Air Technical Service Command 1945*, 69-70.
[51] *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 2.
[52] *History of the Air Technical Service Command 1945*, 68-69.
[53] Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944-1986* (Washington, D.C.: Office of Air Force History, 1988), 11-13.
[54] *Ibid*, 14-18.
[55] *Ibid*, 19-35.
[56] *History of the Air Technical Service Command 1945*, 82-83.
[57] *Ibid*, 86-87.
[58] *Ibid*, 86-88.
[59] *Ibid*, 88.
[60] Research and Development Directorate, Headquarters United States Air Force, *Review of the Site Survey for the AEDC*, 30 December 1948.
[61] Narducci, *A Century of Growth*, 1999, 11-12; B. W. Chidlaw, Deputy Commanding General, Engineering (T-3), to Commanding General, Army Air Forces, "Establishment of an Institute of Technology," three-page memorandum, 8 October 1945, in Irving R. Friend, *History of the Air Technical Service Command 1945 Appendix* (Wright-Patterson Air Force Base: History Office, Air Materiel Command, August 1950).
[62] Frederick A. Alling, *History of the Air Materiel Command 1946*, volume 1 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, March 1951), 83-84.
[63] Max Rosenberg, *History of the Air Materiel Command 1947*, volume 1 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, January 1951), 91.
[64] Karen J. Weitze, *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970* (El Paso: Geo-Marine, Inc., for Air Combat Command, November 1997), 76-79.
[65] *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 11.
[66] George C. McDonald, Brigadier General, Office of the Assistant Chief of Staff, Headquarters, United States Air Forces in Europe, to Major General Hugh J. Knerr, Commanding General, Air Technical Service Command, Wright Field, letter of 3 November 1945, appendix 66 in *Supporting Documents* for Harriet Buyer and Edna Jensen, *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*, Study No. 214 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, August 1948).
[67] Leslie E. Simon, *German Research in World War II: An Analysis of the Conduct of Research* (New York: John Wiley & Sons, Inc., 1947), 12ff, 75-76, 78.
[68] *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 3-7, 13-23.

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[69] *History of the Air Technical Service Command 1945*, 104-106; and, "Twelve Air Technical Service Command Areas Map," *History of the Air Technical Service Command 1945 Appendix.*
[70] *History of the Air Technical Service Command 1945*, 106-118.
[71] *History of the Air Materiel Command 1946*, volume 1, 31-35.
[72] *Ibid*, 3-8.
[73] *Ibid*, 35-43, 92.
[74] *Ibid*, 90-94, 101-104.
[75] *History of the Air Materiel Command 1947*, volume 1, 146-148.
[76] Doris A. Baker, *History of the Air Materiel Command 1948* (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, February 1951), 8.
[77] X [George F. Kennan]," The Sources of Soviet Conduct," in Hamilton Fish Armstrong (ed.), *The Foreign Affairs Reader* (New York and London: Harper & Brothers for the Council on Foreign Relations, 1947), 465-483; Walter Lippmann, *The Cold War: A Study in U.S. Foreign Policy* (New York and London: Harper & Brothers, 1947).
[78] *History of the Air Materiel Command 1948*, 11-13.
[79] *Ibid*, 14-16; Ruth E. Vorce, *History of the Air Materiel Command 1 January – 30 June 1949* (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, May 1951), 7.
[80] *History of the Air Materiel Command 1948*, 33-36; for the dates associated with the tenure of the 4150th Air Base Unit at Robins, see Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 of *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989), 507.
[81] *History of the Air Materiel Command 1948*, 38-40.
[82] *History of the Air Materiel Command 1 January – 30 June 1949*, 11-14.
[83] Gorn, *Harnessing the Genie*, 1988, 44-49.
[84] Frederick A. Alling, Doris A. Baker, Ethel DeHaven, and Max Rosenberg, *History of the Air Materiel Command 1 July – 31 December 1949*, volume 1 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, May 1950), 22.
[85] *Ibid*, 23.
[86] Gorn, *Harnessing the Genie*, 1988, 49.
[87] *History of the Air Materiel Command 1 July – 31 December* 1949, volume 1, 23; *Service Engineering, 1951-1964*, Air Force Logistics Command Historical Study No. 346, volume 2 of *The Engineering Aspects of AFLC Maintenance Responsibility* (Wright-Patterson Air Force Base: Historical Research Division, Air Force Logistics Command, March 1965) in *Mission Activities*, part 2 of Frederick A. Alling, *History of the Air Force Logistics Command 1 July 1962 – 30 June 1963*, volume 1, 5; Gorn, *Vulcan's Forge*, volume 1, 1986, 13-14; Orvil A. Anderson, Donald L. Putt, Ralph P. Swofford, Jr., and Keith K. Compton, "Research and Development in the United States Air Force," Air University Study, 18 November 1949, 6-7 (also numbered pages 1-2).
[88] *History of the Air Materiel Command 1 July – 31 December* 1949, volume 1, 21, 24.
[89] *Ibid*, 28-32.
[90] Gorn, *Vulcan's Forge*, 1986, volume 1, 15-19.
[91] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-1: "Brief Lineage and Honors Data for Air Force Systems Command."
[92] *Service Engineering, 1951-1964*, in *History of the Air Force Logistics Command 1 July 1962 – 30 June 1963*, volume 1, part 2, 6.
[93] Frederick A. Alling, Ethel DeHaven, Max Rosenberg, and S.A. Zimmerman, *History of the Air Materiel Command 1 January – 30 June 1950*, volume 1 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, October 1950), 52-58.
[94] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 6-7: Air Materiel Command, General Orders Number 23, 30 March 1951.
[95] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 6-8: Air Materiel Command, General Orders Number 26, 12 April 1951; Gorn, *Vulcan's Forge*, 1986, volume 1, 19-20.
[96] *Service Engineering, 1951-1964*, in *History of the Air Force Logistics Command 1 July 1962 – 30 June 1963*, volume 1, part 2, 8.
[97] *History of the Air Materiel Command 1 January – 30 June 1950*, volume 1, 189-190.
[98] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-33: "Evolution of Engineering Development Center (AEDC)."
[99] *Ibid*, appendix 1-39: "Evolution of Eastern Space and Missile Center (ESMC)."

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[100] Mueller, *Active Air Force Bases*, 1989, 608.
[101] James F. Aldridge, "Chronology: Basic Research," 21 March 1995, 4.
[102] Gorn, *Vulcan's Forge*, 1986, volume 1, 21.
[103] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-10: "Evolution of Air Force Armament Center (AFAC)."
[104]Ernest G. Schwiebert, *Reorganization of the Air Research and Development Command*, book 1 of volume 1 of *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, 37.
[105] *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 3, 163.
[106] *Reorganization of the Air Research and Development Command*, book 1 of *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 1, 36-38, 91.
[107] Gorn, *Vulcan's Forge*, 1986, volume 1, 24.
[108] Gorn, *Vulcan's Forge*, 1986, volume 1, 21; *History of the Air Materiel Command 1 January – 30 June 1949*, 133.
[109] *History of the Air Materiel Command 1 January – 30 June 1950*, volume 1, 326-327.
[110] *Ibid*, 329-332.
[111] Helen Brents Joiner, *History of Army Ballistic Missile Agency 1 February – 30 June 1956*, 78.
[112] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 81-83, 168-169; Air Technical Intelligence Center, *History of Air Technical Intelligence Center 1 January 1952 – 30 June 1952*, volume 6, 33ff.
[113] *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 3, 144-145, 153, 155-157, 162-163.
[114] Headquarters ARDC first occupied the Sun Building in downtown Baltimore, leasing the Hillen Building at 420 Fallsway as a second structure for the command's initial administration. The command leased an additional 17,000 square feet of storage at 600 Fallsway. Airmen's housing for Headquarters ARDC occupied Goucher Hall, with further facilities at Baltimore's civilian airport. *Ibid*, 146-147; Gorn, *Vulcan's Forge*, 1986, volume 1, B-3.
[115] Gayle L. Smith, Deputy Director of Air Installations, memorandum to Director of Installations, Headquarters United States Air Force, 14 April 1952, in File "Contracts January-May 1952," 1 of 2, Box 279, Entry 494, Record Group 341, National Archives II; *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 3, 145-147, 153-155; Gorn, *Vulcan's Forge*, 1986, volume 1, B-4.
[116] Gorn, *Harnessing the Genie*, 1988, 48-50.
[117] Public Information Office, Headquarters Air Research and Development Command, *U.S. Air Force Research and Development Accomplishments in 1952: A Special Report* (Baltimore: Air Research and Development Command, 29 March 1953).
[118] D.L. Putt, Lieutenant General, Commander ARDC, "A Message from ARDC," *Aviation Week* 59, 7 (17 August 1953): 72.
[119] "ARDC Molds U.S. Air Development," *ibid*, 74.
[120] *Ibid*, 75.
[121] *Ibid*, 75, 78-79.
[122] *Ibid*, 79.
[123] *History of the Air Materiel Command 1 January – 30 June 1950*, volume 1, 186.
[124] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 87-90.
[125] "ARDC Molds U.S. Air Development," *Aviation Week*, 17 August 1953, 79-80.
[126] "Air Research and Development Command Edition," *ibid*, 72-414.
[127] "Airman Survival is Aero Med's Big Job," *ibid*, 392-410.
[128] *Ibid*, 392.
[129] *Ibid*, 394.
[130] Gorn, *Vulcan's Forge*, 1986, volume 1, 22-49.
[131] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-2: "Evolution of Air Force Systems Command (AFSC)."
[132] Gorn, *Vulcan's Forge*, 1986, volume 1, 51-56.
[133] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-8: "Evolution of Air Defense Systems Integration Division (ADSID)."
[134] Gorn, *Vulcan's Forge*, 1986, volume 1, 57-63.
[135] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-18: "Evolution of Air Force Geophysics Laboratory (AFGL)."
[136] Gorn, *Vulcan's Forge*, 1986, volume 1, 66.
[137] *Ibid*, 63-70.

[138] For a detailed discussion of the evolution of the laboratories at Wright-Patterson Air Force Base see: James F. Aldridge, *A Historical Overview of the Mission and Organization of the Wright Laboratory 1917-1993*, Draft (Wright-Patterson Air Force Base: History Office, Aeronautical Systems Center, Air Force Materiel Command, November 1994).
[139] Gorn, *Vulcan's Forge*, 1986, volume 1, 68-72.
[140] Mueller, *Active Air Force Bases*, 1989, 12, 56, 250, and 609.
[141] Gorn, *Vulcan's Forge*, volume 2, 1986, appendices 1-7: "Evolution of Aerospace Research Laboratories (ARL)" and 1-48: "Evolution of Office of Aerospace Research (OAR)."
[142] Mueller, *Active Air Force Bases*, 1989, 12, 47.
[143] Gorn, *Vulcan's Forge*, volume 2, 1986, appendices 1-9, 1-11, 1-12, 1-16,1-201-24, and 1-50.
[144] Gorn, *Vulcan's Forge*, 1986, volume 1, 103-105.
[145] Air Force Systems Command, *History of Air Force Systems Command 1 July 1968 – 30 June 1969*, volume 1, 36-37.
[146] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-39.
[147] *Ibid*, appendix 1-47: "Evolution of National Range Division (NRD)."
[148] Mueller, *Active Air Force Bases*, 1989, 573; Gorn, *Vulcan's Forge*, 1986, volume 1, 105; Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-52: "Evolution of Space and Missile Test Organization (SAMTO)."
[149] Mueller, *Active Air Force Bases*, 1989, 465.
[150] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-55: ""Evolution of Western Space and Missile Center (WSMC)."
[151] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 23; Mueller, *Active Air Force Bases*, 1989, 248.
[152] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-15: "Evolution of Air Force Contract Management Division (AFCMD)" and appendix 1-36: "Evolution of Central Contract Management Region (CCMR);" Mueller, *Active Air Force Bases*, 1989, 293.
[153] Gorn, *Vulcan's Forge*, 1986, volume 1, 105.
[154] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-7.
[155] *History of Air Force Systems Command 1 July 1968 – 30 June 1969*, volume 1, 36-37, 187-191.
[156] Gorn, *Vulcan's Forge*, 1986, volume 1, 111.
[157] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-43: "Evolution of the Frank J. Seiler Research Laboratory (FJSRL)."
[158] *Ibid*, appendix 1-22: "Evolution of Air Force Office of Scientific Research (AFOSR)."
[159] *Ibid*, appendix 1-14: "Evolution of Air Force Civil Engineering Center (AFCEC)."
[160] Gorn, *Vulcan's Forge*, 1986, volume 1, 112.
[161] Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-41: "Evolution of the European Office of Aerospace Research and Development (EOARD)."
[162] *Ibid*, 113.
[163] *Ibid*, 113; Mueller, *Active Air Force Bases*, 1989, 573.
[164] Gorn, *Vulcan's Forge*, 1986, volume 1, 114.
[165] Gorn, *Vulcan's Forge*, volume 2, 1986, appendices 1-19: "Evolution of Air Force Human Resources Laboratory (AFHRL);" 1:44: "Evolution of Human Factors Operations Research Laboratories (HFORL);" 1-45: "Evolution of Human Resources Research Center (HRRC);" and, 1-46: "Evolution of Human Resources Research Institute (HRRI)."
[166] Gorn, *Vulcan's Forge*, 1986, volume 1, 25, 114.
[167] Master Sergeant Gary R. Akin, Jean August, Paul C. Ferguson, Lieutenant Colonel Beverly S. Follis, Layne B. Peiffer, William W. Suit, Lois E. Walker, and John D. Weber, *Closeout History Air Force Systems Command 1 October 1990 – 30 June 1992 and Air Force Logistics Command 1 October 1991 – 30 June 1992*, volume 1 (Wright-Patterson Air Force Base: Office of the Command Historian, July 1993), 28.
[168] *Ibid*, 28-31.
[169] Ruth P. Liebowitz and Paul A. Maria, *A Historical Chronology of Hanscom Air Force Base 1941 – 1997* (Hanscom Air Force Base: History Office, Electronics Systems Center, 1997), 26.
[170] *Closeout History Air Force Systems Command 1 October 1990 – 30 June 1992 and Air Force Logistics Command 1 October 1991 – 30 June 1992*, volume 1, 31-35.
[171] *History of the Air Materiel Command 1946*, volume 1, 42-46.
[172] *Ibid*, 66. With the possible exception of the Army airfield in Independence, these locations were all in arid settings, either of desert or plains type. Pyote, Texas, is correctly spelled without the "e" (Peyote), and is a

small community due south of Hobbs, New Mexico, along the I-20 corridor between Pecos and Odessa. See also, Bernard J. Termena, Layne B. Peiffer, and H.P. Carlin, *Logistics: An Illustrated History of AFLC and Its Antecedents, 1921-1981* (Wright-Patterson Air Force Base: Office of History, Air Force Logistics Command, ca.1981), 81-85.
[173] Aeronautical Systems Division, Air Force Systems Command, *USAF Industrial Plant Ownership Responsibilities* (Wright-Patterson Air Force Base: Air Force Systems Command, ca.1986), 12.
[174] The name "Warner Robins" derives from that of Brigadier General Augustine Warner Robins (1882-1490). The depot had several earlier formal names before that of Warner Robins, with its airfield commonly known as Robins Field during World War II. The nearby community was, and remains, that of Warner Robins. The installation evolved into Robins Air Force Base, but the depot always maintained "Warner Robins" in its title. Adding to the confusion, the spelling "Warner-Robins" is present in Air Materiel Command histories of the post-World War II period.
[175] *History of the Air Materiel Command 1946*, volume 1, 67-68.
[176] *History of the Air Materiel Command 1947*, volume 1, 78-79.
[177] Air Materiel Command, "Air Materiel Area Boundaries" and "Organization (Field): Geographical Composition and Jurisdictional Limits of Air Materiel Areas," AMC Regulation No. 21-42, 6 May 1947, in *History of the Air Materiel Command 1947*, volume 2.
[178] *History of the Air Materiel Command 1947*, volume 1, 26.
[179] *Ibid*, 24-25.
[180] *History of the Air Materiel Command 1948*, 85.
[181] *Ibid*, 86.
[182] *Ibid*, 86-88; *History of the Air Materiel Command 1 January – 30 June 1949*, 107-110, 119-120; Benjamin H. Williams and Lowell L. Henkel, *Requirements*, volume 11 in *The Economics of National Security* (Washington, D.C.: Industrial College of the Armed Forces, revised 1956, 11th printing of March 1963), 31-32.
[183] *History of the Air Materiel Command 1948*, 89-90.
[184] *History of the Air Materiel Command 1 January – 30 June 1949*, 5.
[185] "AMC Areas and Activities," 1 December 1949, in *ibid.*
[186] *Ibid*; *History of the Air Materiel Command 1 July – 31 December* 1949, volume 1, 27-28.
[187] *Ibid*, 129-132.
[188] Frederick A. Alling, Ethel M. DeHaven, Helen Brents Joiner, and Clifford A. Morrison, *History of the Air Materiel Command 1 January – 30 June 1951*, volume 1 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, November 1951), 278-281.
[189] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 37-43, 52-55.
[190] *History of the Air Materiel Command 1 January – 30 June 1951*, volume 1, 291.
[191] Q clearances are distinct from the hierarchy of security levels within the Air Force and Army, but are parallel in weighting to a Top Secret clearance.
[192] Marna B. P. Courson, with Jane Flynn and Dory DeAngelo, *Black & Veatch 1915-1990* (Kansas City: Black & Veatch, 1992), 71, 133-137; Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 97-107.
[193] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 98.
[194] Air Materiel Command, General Orders Number 76, 16 November 1950, in Air Materiel Command, *History of Air Materiel Command Participation in the Atomic Energy Program April – December 1951*, volume 2.
[195] Air Materiel Command, AMC Organizational Directive No. 23-2, 5 March 1951, in *ibid.*
[196] "Directed Procurement for Architect-Engineer Services," memorandum from Headquarters United States Air Force, to the commanding general, Air Materiel Command, Wright-Patterson Air Force Base, 28 April 1951, in *ibid.* Included are additional memoranda into March 1952.
[197] *History of the Air Materiel Command 1 January – 30 June 1951*, volume 1, 292.
[198] These depots likely carry the 14 alpha designations missing from between the A-L and Y Sites in the continental United States. Primary sources support this for at least a known grouping overseas. Minimal information on the individual sites in the United States is presented in: Daniel R. Bilderback and Michael S. Binder, *Early DoD-Sited Nuclear Warhead Infrastructure Final Report* (Columbia, South Carolina, and, Dallas, Texas: University of South Carolina and MILSITE RECON, for the Department of Defense, May 1999). The Bilderback and Binder study makes deductions across a wide range of unclassified sources.
[199] Terminology for nuclear materiel depots is confusing and should be interpreted carefully until more definitive assessment of the Air Force lineage is accomplished. "Aviation Depot Squadrons," while including the early Q Areas—such as that of the 3080th Aviation Depot Squadron at Loring—is also how the Air Force

delineated other depot units responsible for nuclear weapons storage. For example, the 54th Aviation Depot Squadron at Eglin references the unit responsible for the nuclear-tipped Hound Dog missile of the late 1950s into the middle 1960s. (Aviation Depot Squadrons are also distinct from Aviation Squadrons.) Aviation Field Depot Squadrons are associated only with training units at Kirtland, and include units predominantly enroute to overseas. Once operational under SAC, the Aviation Field Depot Squadrons converted to Aviation Depot Squadrons that retained their original numbering. For example, the 1st Aviation Field Depot Squadron at Kirtland of November 1950 through May 1951 became the 1st Aviation Depot Squadron. In several cases, an even more tangled situation occurred. Several of the Q Areas in the continental United States supported simultaneous Aviation Depot Squadrons and Aviation Field Depot Squadrons, with distinct numbering for each. The 11th Aviation Field Depot Squadron, for example, complemented Loring's 3080th Aviation Depot Squadron in early 1953. Many of the histories for the Aviation Field Depot Squadrons are held at the Air Force Historical Research Agency.

[200] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 98.

[201] *History of the Air Materiel Command 1 January – 30 June 1951*, volume 1, 291-293.

[202] Termena, Peiffer, and Carlin, *Logistics*, ca.1981, 112ff.

[203] Air Materiel Command, *History of the Air Materiel Command 1 January – 30 June 1952*, volume 1, 232.

[204] Air Materiel Command, *History of the Air Materiel Command 1 July – 31 December 1952*, 431; R.H. Curtin, Directorate of Installations, Deputy Chief of Staff, Operations, "Approval of USAF Warehouse Program," memorandum to the Director of Installations, Office of the Secretary of Defense, 17 September 1952, and, Frank R. Creedon, Director of Installations, Office of the Secretary of Defense, "Depot Warehouses," memorandum to the Assistant Secretary of the Air Force (Materiel), 18 November 1952, both in File "Warehouses 1952," Box 304, Entry 494, Record Group 341, National Archives II.

[205] Doris A. Baker, Ethel M. DeHaven, Maurer Maurer, Dorothy L. Miller, Mary R. Self, and E. Clifford Snyder, *History of the Air Materiel Command 1 January – 30 June 1953*, volume 1 (Wright-Patterson Air Force Base: Historical Branch, Air Materiel Command, January 1954), 246-250.

[206] Maurer Maurer and Paul M. Davis, *History of the Air Materiel Command 1 July – 31 December 1953*, volume 1 (Wright-Patterson Air Force Base: Historical Division, Air Materiel Command, May 1954), 227-234; Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 98; Hibbard, "Closure of Air Materiel Areas and Air Force Depots," 1986. The transportation control depots corresponded to the much earlier Atlantic and Pacific Overseas Air Service Commands (1943-1944); the Atlantic and Pacific Overseas Air Technical Service Commands (1944-1946); and, the Atlantic and Pacific AMAs (1946-1947)—each in Newark, New Jersey, and, Stockton, California, respectively.

[207] Termena, Peiffer, and Carlin, *Logistics*, ca.1981, 137-139.

[208] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 145 and 150.

[209] Drawings for the Special AMC Warehouse exist in complete and partial sets at the former Griffiss, Hill, Kelly, McClellan, Tinker, and Robins Air Force Bases, as reviewed by the author between December 1999 and November 2000. See bibliography in Volume II for specific drawing entries, under L.P. Kooken.

[210] "Warehouse Failures Pinpointed," *Engineering News-Record* 156, 2 (12 January 1956): 21.

[211] Hibbard, "Closure of Air Materiel Areas and Air Force Depots," 1986. Listed depots give dates of opening and closing, and strongly suggest a match with locations of the Special AMC Warehouse.

[212] See L.P. Kooken drawings listed in the bibliography, Volume II.

[213] The most illuminating set of drawings for the Special AMC Warehouse is that held in the civil engineering vault at Hill Air Force Base.

[214] Arsham Amirikian, Bureau of Yards and Docks, Department of the Navy, "Promising future predicted for precast thin-shell construction," *Civil Engineering* 23, 8 (August 1953): 42.

[215] *Ibid*, 42-44.

[216] "Walls in Navy Housing," *Architectural Record* 110, 5 (November 1951): 177-178.

[217] Clarence P. Green and Karl C. Vogel, "Lift Slab Construction," *The Military Engineer* 45, 308 (November-December 1953): 427-429.

[218] "Tilt-Up Building for Industrial District," *Architectural Record* 111, 2 (February 1952): 188-189.

[219] "New Type Hangars Go Up Around the World," *Engineering News-Record* 154, 19 (12 May 1955): 34-36, 38.

[220] Marvin E. Warner and David P. Billington, "Precast Concrete shows 21-percent saving on air-base buildings," *Civil Engineering* 27, 4 (April 1957): 33-37.

[221] "Thin-shell experts exchange 'know-how'," *Engineering News-Record* 153, 1 (1 July 1954): 25.

[222] "Warehouse Failures Pinpointed" and "Failure Sparks More Studies," *Engineering News-Record*: 156, 2 (12 January 1956): 21-23, and, 157, 3 (27 September 1956): 28.
[223] "Precasting 35 Acres of Roof Panels for Warehouse," *Engineering News-Record* 158, 22 (30 May 1957): 42-43.
[224] Lloyd S. Spancake, Mary C. Whalen, and Howard G. Clark, *History of Middletown Air Materiel Area 1 January – 30 June 1958*, volume 1, 34-36, 212-213, 221-222.
[225] *Ibid*, photographs.
[226] "Cast-in-Place Concrete Shell Structure Bid Below Price of Precast Structure," *Civil Engineering* 27, 9 (September 1957): 101.
[227] David P. Billington and Eric M. Hines, "Anton Tedesko, Model Research and the Introduction of Thin Shells into the United States," offprint of an unidentified article held in the Tedesko archives at the civil engineering department at Princeton University. Offprint contains tables of measurements and test information for Tedesko thin-shell long and short barrel structures in Europe and the United States, with photographs of the test shells of 1931 and 1950.
[228] "Dischinger, Franz," a short biography posted in German at www.luise-berlin.de by Edition Luisenstadt, 1998. Dischinger died on 9 January 1953, making his whereabouts between his teaching stint at the Technical University in West Berlin during 1946 and 1951, and his death, still a gap that the author has not filled.
[229] David P. Billington, "Anton Tedesko: Thin Shells and Esthetics," *Journal of the Structural Division, Proceedings of the American Society of Civil Engineers* 108, ST11 (November 1982): 2539-2554.
[230] Air Command and Staff College, "Development of Air Weapon Systems," *ACSC-19*, Maxwell Air Force Base, 21 July 1958, 24; Gorn, *Vulcan's Forge*, volume 2, 1986, appendix 1-41: "Evolution of Office of Aerospace Research and Development (EOARD)."
[231] Billington, "Anton Tedesko: Thin Shells and Esthetics," *Journal of the Structural Division, Proceedings of the American Society of Civil Engineer*, November 1982, 2547.
[232] Lloyd S. Spancake, Mary C. Whalen, and Howard G. Clark, *History of Middletown Air Materiel Area 1 July – 31 December 1957*, 57.
[233] Assistant Chief of Staff, Installations, *History of the Assistant Chief of Staff, Installations 1 January – 30 June 1957*, volume 8, 55-56.
[234] Lloyd S. Spancake, Mary C. Whalen, and Phoebe E. Burns, *History of Middletown Air Materiel Area 1 July – 31 December 1958*, volume 1, 51.
[235] Termena, Peiffer, and Carlin, *Logistics*, ca.1981, 139.
[236] *Ibid*, 122-123.
[237] *Ibid*, 125, 127.
[238] Royal D. Frey and Frederick A. Alling, *History of the Air Materiel Command 1 January – 30 June 1958*, volume 1, 104-105.
[239] Termena, Peiffer, and Carlin, *Logistics*, ca.1981, 128-131, 144-145.
[240] *Service Engineering, 1951-1964*, in *History of the Air Force Logistics Command 1 July 1962 – 30 June 1963*, volume 1, part 2, 26-32.
[241] Termena, Peiffer, and Carlin, *Logistics*, ca.1981, 135.
[242] *History of the Air Materiel Command 1 January – 30 June 1958*, volume 1, 96-97.
[243] *Ibid*.
[244] Gorn, *Vulcan's Forge*, 1986, volume 1, 67.
[245] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 227-247, 261-265.
[246] Termena, Peiffer, and Carlin, *Logistics*, ca.1981, 171-181.
[247] Gentile Air Force Station stayed open until the middle 1990s, when this long-lived and important logistics installation ceased operations under Base Realignment and Closure (BRAC).
[248] The two thin-shell ribless warehouses today appear to be near, or within, the boundaries of the campus of Pennsylvania State University at Harrisburg.
[249] Termena, Peiffer, and Carlin, *Logistics*, ca.1981, 181-195; Hibbard, "Closure of Air Materiel Areas and Air Force Depots," 1986; Mueller, *Active Air Force Bases*, 1989, 208; "Guide to Air Force Bases," *Air Force and Space Digest* 53, 5 (May 1970): 163, 171.
[250] Termena, Peiffer, and Carlin, *Logistics*, ca.1981, 212-213.
[251] *Closeout History Air Force Systems Command 1 October 1990 – 30 June 1992 and Air Force Logistics Command 1 October 1991 – 30 June 1992*, volume 1, 1993, 6.

[252] Dr. Paul Ferguson, of the History Office, Air Force Materiel Command, at Wright-Patterson, provided the detailed BRAC chronology for McClellan and Kelly.
[253] Narducci, *A Century of Growth*, 1999, 18-19.
[254] Philip Shiman, *Forging the Sword: Defense Production during the Cold War*, USACERL Special Report 97/77 (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, July 1997), 15.
[255] Trnka and Manley, *Air Force Plant 4 Fort Worth, Texas*, 1997, 3-1 to 3-2.
[256] *Engineering News-Record*: "This aircraft factory built in 40 days," 125, 7 (15 August 1940): 32; "Rapid Expansion of Engine Plant Leaves Time for Improvements," 125, 17 (24 October 1940): 70-71; and, "Fifteen-Acre Plant for Bombers Built in 90 Days," 125, 17 (24 October 1940): 72-76.
[257] "Fast work on plane plant in spite of severe mud," *Engineering News-Record* 126, 5 (30 January 1941): 24.
[258] Three examples discussed and illustrated in *Engineering News-Record* are: "Studebaker adopts blackout design for its airplane engine plants [for Wright airplane engines: Giffels & Vallet, with L. Rossetti, Detroit]," News Issue (20 March 1941): 3; "Buick begins its 1,000,000 sq. ft. aircraft engine plant [for Pratt & Whitney aircraft engineers: Albert Kahn, Detroit]," News Issue (3 April 1941): 6; and, "Packard Adds a Plane Engine Plant [for Rolls-Royce Merlin aircraft engines: Albert Kahn, Detroit]," 127, 11 (11 September 1941): 80-83.
[259] Articles on the aircraft manufacturing plants begin to appear steadily in *Engineering News-Record* as of July 1940, continuing through 1944. Specific mention of the responsible architect-engineer is nearly always present. See also, Joseph Trnka, Terri Wessel, and William Manley, *Historic Building Inventory and Evaluation of Air Force Plant PJKS, Jefferson County, Colorado* (Colton, California: Earth Tech, Inc., and William Manley Consulting for Air Force Materiel Command, Aeronautical Systems Center, February 1997), 3-14.
[260] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 102.
[261] "Fast work on plane plant," *Engineering News-Record*, 30 January 1941.
[262] *Engineering News-Record*: "Building a Blackout Plane Plant," 126, 19 (8 May 1941): 64-66, and, "A 22-acre bomber plant in Middle West," News Issue (15 May 1941): 4-5.
[263] "Plane Engine Plant Sets New Precedents," *Engineering News-Record* 127, 5 (31 July 1941): 48-53.
[264] "New Plants to Build Airplanes—Engines—Propellers," *Engineering News-Record* 126, 7 (13 February 1941): foldout between page 128 and 129. Numbers for each of these firms may be higher, as not all are given, and typically a consulting architect's contribution masks design work by engineering firms such as Turnbull's (and vice versa).
[265] Joseph Trnka and Terry Wessel, *Historic Building Inventory and Evaluation: Air Force Plant 85, Columbus, Ohio* (Colton, California: Earth Tech, Inc., with assistance from Commonwealth Cultural Resources Group, Jackson, Michigan, for Air Force Materiel Command, Aeronautical Systems Center, Wright-Patterson Air Force Base, 1996), 3-14.
[266] R.W. Stuck, "Huge Aircraft Assembly Plant Built in Marietta, Ga.," *Civil Engineering* 14, 3 (March 1944): 93-97.
[267] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 90-97.
[268] War Department, "Special Report on 15 [Modification] Centers," 2 February 1945, 1-8, and, attached typescript "The Procurement Division Modification Program." Also referenced in a "recommended reading" section of the typescript is: Virginia Toole, Historical Branch, Wright Field, "The Modification of Aircraft: Procedures, Policies & Problems," undated.
[269] Dayton Army Air Field, appendix to "A History of the Dayton Army Air Field, Vandalia, Ohio, for the Year 1944," 1 July 1945. See also, Note 261.
[270] War Department, "Special Report on 15 [Modification] Centers" and "The Procurement Division Modification Program," February 1945.
[271] Trnka and Manley, *Air Force Plant 4 Fort Worth, Texas*, 1997, 3-3.
[272] "Wartime Lessons for Peacetime Building: These War Buildings Were Significant," *Engineering News-Record* 133, 16 (19 October 1944): 109-118. See also, *Engineering News-Record*: "Building Bomber Assembly Plants," 127, 17 (23 October 1941): 133-136, and, "Steel framework complete on Fort Worth Bomber Plant," News Issue (27 November 1941): 6.
[273] "Wartime Lessons for Peacetime Building," *Engineering News-Record*, 19 October 1944. Tedesko also appears to have designed and engineered a laminated wooden arch hangar similar to those at Vandalia for Northwest Airlines in Fargo, North Dakota, during this period. The Fargo hangar featured a span of 152 feet. Exterior and interior construction photographs are extant in the Tedesko archives at the civil engineering department of Princeton University.

[274] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 60-67.
[275] Trnka and Manley, *Air Force Plant 4 Fort Worth, Texas*, 1997, 3-4 and 3-5.
[276] Trnka and Wessel, *Air Force Plant 85, Columbus, Ohio*, 1996, 3-26 – 3-29.
[277] Air Policy Commission, "Aircraft Manufacturing Industry," *Survival in the Air Age: A Report to the President's Air Policy Commission*, 1 January 1948, 45-70.
[278] Shiman, *Forging the Sword*, 1997, 39-41.
[279] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 123, 126-127; and, Trnka and Wessel, *Air Force Plant 85*, 1996, 3-26 – 3-29. Lustron discussion, including an analysis of articles in *Engineering News-Record* and an Air Proving Ground Command test report, appears in *Eglin Air Force Base, 1931-1991.* Air Materiel Command considered prefabricated Lustron houses for possible use in the Arctic, testing a full-sized house in the climatic hangar at Eglin during late 1948 and early 1949.
[280] *History of the Air Materiel Command 1946*, volume 1, 149-152.
[281] *Ibid*, 153-154.
[282] *Ibid*, 155.
[283] *Ibid*, 157.
[284] *History of the Air Materiel Command 1947*, volume 1, 195-205.
[285] *History of the Air Materiel Command 1948*, 71.
[286] *Ibid*, 72-73.
[287] *History of the Air Materiel Command 1 January – 30 June 1949*, 93.
[288] *History of the Air Materiel Command 1948*, 74
[289] *History of the Air Materiel Command 1 July – 31 December* 1949, volume 1, 117-118.
[290] *History of the Air Materiel Command 1948*, 75; *History of the Air Materiel Command 1 July – 31 December 1949*, volume 1, 118-119.
[291] Industrial Planning Division, untitled communication to the Chief of Staff [Air Force], ca.1948, with attached communications from the Commanding General Air Materiel Command, Wright-Patterson Air Force Base, in File "Plant Relocation General File," Box 37, Entry 464, Record Group 341, National Archives II.
[292] Shiman, *Forging the Sword*, 1997, 44-45.
[293] Industrial College of the Armed Forces, *Production*, volume in *The Economics of National Security* (Washington, D.C.: Industrial College of the Armed Forces, 1957, 11th printing 1963), 76-77.
[294] *History of the Air Materiel Command 1948*, 65-67.
[295] *Ibid*; Paul C. Ferguson, History Office, Air Force Materiel Command, analysis and discussions with the author, 26 October 2001.
[296] "AF Procurement Field Offices and Boundaries Map," *History of the Air Materiel Command 1 July – 31 December 1949*, volume 2, appendix A-5.
[297] Headquarters Air Materiel Command, General Orders Number 45, 24 August 1953, in Ruby F. Brothers, *History of the Gentile Air Force Depot 1 October 1953 – 30 June 1954.*
[298] Air Materiel Command, "Government Aircraft Plants," *Histories of AMC Field Installations and Organizations* (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, December 1948), unpaginated. Although this document is a list of completed histories, by inclusive dates, for Air Materiel Command units, the identification of GAP histories is useful as an indication of which plants were under Air Materiel Command jurisdiction for the 1946-1948 period. GAP No. 1, in Omaha, is also included on a map, "AMC Areas and Activities," of 1 December 1949, in *History of the Air Materiel Command 1 January – 30 June 1949*, 17, suggesting that the plant was either still functional for the command as a standby plant (the definition of a GAP) or had just passed to SAC at Offutt. With SAC's takeover of Offutt in October 1948, the Martin plant (GAP No. 1) ceased functioning as an industrial facility and became part of the infrastructure of the base.
[299] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 100-103.
[300] *History of the Air Materiel Command 1 January – 30 June 1949*, 15-16.
[301] *Ibid*, "AMC Areas and Activities," 17.
[302] Stephen I. Schwartz, Director, U.S. Nuclear Weapons Cost Study Project, The Brookings Institute, *U.S. Nuclear Weapons Research, Development, Testing, and Production, and Naval Nuclear Propulsion Facilities*, revised, 12 October 1999, 10, 18-19. As posted at www.brook.edu/fp/projects/nucwcost/sites.
[303] Air Force Systems Command, *Facilities Contracts Leases Industrial Management Report*, 1976, 22. Dr. Paul Ferguson of the History Office, Air Force Materiel Command, graciously provided his working research on AFP lineage, allowing the author to establish the Mobile AMA date of 19 March 1956 for the

Adrian plant. Dr. Ferguson also forwarded a copy of the Headquarters Air Force Logistics Command Special Orders G-120 of 15 September 1961, listing the industrial facilities transferred from AFLC to AFSC effective 1 July 1961.
[304] Aeronautical Systems Center, Air Force Materiel Command, "Air Force Installation / Plant Identification," ca. January 1995. List provided by Frank Tokarsky, Aeronautical Systems Center, Wright-Patterson Air Force Base. See also: Air Force Systems Command, *Facilities Contracts Leases*, 1976, 3, 25; "Air Force Plant 70," *USAF Industrial Plant Ownership Responsibilities*, ca.1986, 42-43; and, Shiman, *Forging the Sword*, 1997, 118, 149-150.
[305] Shiman, *Forging the Sword*, 1997, 45-53, 56.
[306] *History of the Air Materiel Command 1 July – 31 December 1953*, volume 1, 231.
[307] Shiman, *Forging the Sword*, 1997, 113.
[308] *USAF Industrial Plant Ownership*, ca.1986, 23.
[309] *Aviation Week*: "Plant Layout Settled for Atlas," 65, 4 (23 July 1956): 58, and, Irving Stone, "Human Factors Stressed in Atlas Plant," 66, 20 (20 May 1957): 53-57.
[310] *Aviation Week*: Irving Stone, "Thor Designed for Fast Mass Production," 67, 22 (2 December 1957): 26-28, and, "Static Facility Complex Prepares Ballistic Missiles for Launching," 67, 23 (9 December 1957): 50-51.
[311] Trnka, Wessel, and Manley, *Air Force Plant PJKS*, 1997. See also: *Aviation Week*: J.S. Butz, "Plans Detailed for Titan Complex Design," 70, 7 (16 February 1959): 27-29, and, Russell Hawkes, "Hardened Titan Bases Require Specialized Support," 72, 3 (18 January 1960): 66-80.
[312] Joseph Trnka and Norman Rajotte, *Historic Building Inventory and Evaluation of Air Force Plant 44, Tucson, Arizona* (Colton, California: Earth Tech, Inc., and Research Management Consultants, Inc., for Air Force Materiel Command, Aeronautical Systems Center, December 1996).
[313] Shiman, *Forging the Sword*, 1997, 54-60
[314] *Ibid*, 55.
[315] Air Force Systems Command, *Facilities Contracts Leases*, 1976, 21. Number and chronology of active Air Force plants in 1958-1959 are in conflict in official Air Force sources. Shiman relied on the United States House Committee on Armed Services, Subcommittee on Special Investigations, *Utilization of Government-Owned Plants and Facilities*, 1959, for his figure of 80 in December 1958. In a bar graph included in *Facilities Contracts Leases* of 1976, AFSC showed about 93 active plants in 1958 and about 91 in 1959. Both sources indicate a peaking at the end of the 1950s.
[316] Shiman, *Forging the Sword*, 1997, 53, 69.
[317] Air Force Systems Command, *Facilities Contracts Leases*, 1976, 21.
[318] See Note 283.
[319] Air Force Systems Command, *Facilities Contracts Leases*, 1976, 21.
[320] *Ibid*, iii, 19.
[321] Industrial College of the Armed Forces, *Production*, 1963, 79-80.
[322] Lloyd S. Spancake, *History of Middletown Air Materiel Area 1 July 1959 – 30 June 1960*, volume 1, 240-246.
[323] Alpha designations for the plants are not addressed here. Examples range from AFP 3: ACFH, AFP 4: ACFJ, and AFP 6: ACFL, which are similar, to AFP 42: TTQK, AFP 43: ACGZ, and AFP 44: ACHA, which are more differentiated.
[324] Air Force Systems Command, *Facilities Contracts Leases*, 1976, iv.
[325] *Ibid*, 20.
[326] *Ibid*, 73-74.
[327] *Ibid*, 21.
[328] Shiman, *Forging the Sword*, 1997, 80-81.
[329] *USAF Industrial Plant Ownership*, ca.1986, 2.
[330] *Ibid*, 81.
[331] Air Force Systems Command, *Facilities Contracts Leases*, 1976, 22-25.
[332] *USAF Industrial Plant Ownership*, ca.1986, *passim.*
[333] *Closeout History Air Force Systems Command 1 October 1990 – 30 June 1992 and Air Force Logistics Command 1 October 1991 – 30 June 1992*, volume 1, 1993, 43-45.
[334] Shiman, *Forging the Sword*, 1997, 163-164.
[335] *Ibid*, 149-150.

[336] Email communication, from Frank Tokarsky, Aeronautical Systems Center, Wright-Patterson Air Force Base, to Karen J. Weitze, 14 June 2002.
[337] "AF Industrial Plant Locations," annotated map provided by Frank Tokarsky, Aeronautical Systems Center, Wright-Patterson Air Force Base.

Part III: The Rise of Science, Engineering, and Technology after 1945

The most resounding characteristic of the Air Force materiel mission is the central presence of scientific, engineering, and technological achievement. Even before the end of World War II, every aspect of the meteoric rise for a science-defined modernism was in place for what would become today's Air Force Materiel Command. At Wright Field, a theory of the future received a double push from the historic reality of the Wright brothers aircraft testing in Dayton, Ohio, early in the century, and, from the receipt of German missiles components by Army Air Forces Materiel Division in 1944. An advancing knowledge of rocketry in Germany, with an eye toward the frontier of space, was particularly motivational. While engineer Robert H. Goddard had proposed as early as 1919 that a rocket would one day reach the moon, his research and writings in Massachusetts and New Mexico had remained obscure to his fellow Americans throughout his life. Goddard's work, however, had influenced the full spectrum of Germany's rocket scientist community, as well as affecting its popular culture through illustrated books such as *Der Vorstoss in den Weltenraum* (*The Advance into Outer Space*) of 1924 and several early silent films climaxing in Fritz Lang's *Frau im Mond* (*The Woman in the Moon*) of 1929. Not without irony did Dr. Franckel, a technical advisor to the European Theater of Operations, return with parts of a V-1 to Wright Field in mid-1944—in many ways bringing the visions of Goddard, as foreshadowed in *Frau im Mond* and made real by German scientists and engineers, back home. As Air Materiel Command advanced after World War II, the outcome of the conflict literally brought German scientists and engineers to American soil through Project Paperclip, and its follow-on efforts, into the middle 1950s. German materiel, technical papers, and personnel contributed significantly to the direction of the air materiel mission after the war. Even Intelligence (T-2), within Air Materiel Command, derived largely from the study of acquired items, with an emphasis on their potential for research and development (R&D).

Indeed, science fiction during the jazz age, more so than science, prepared the public for serious research—also offering curious insights. From the late 1920s forward, special effects and all that Hollywood came to represent, became inseparable from the high-tech future. Director Lang had fled Nazi Germany in 1932, arriving in the United States via France as of 1935. In *Frau im Mond*, Lang had been the first to conceive the rocket countdown sequence, advised in his making of the movie by real-life scientist Hermann Oberth. With intertwined irony, Professor Oberth worked with Dr. Wernher von Braun and the rocketry group at Peenemünde during World War II, subsequently rejoining Paperclippers and later recruits between 1955 and late 1958 at the Army's Redstone Arsenal in Huntsville, Alabama, before returning to Germany to teach. Lang too was back in Germany as of 1959, making films there into the early 1960s. A culminating linkage between Lang, Oberth, and the evolved von Braun group of the Cold War came at the outset of the era of the National Aeronautics and Space Administration (NASA). In 1961, Professor Oberth flew from Germany to Huntsville to address a NASA space science seminar at its new Marshall Space Flight Center. In 1964, director Lang also went to Marshall to lecture, and to personally narrate a showing of his late 1920s *Frau im Mond*. Lang's audience in Huntsville included a large number of the original German rocket scientists, many transferred from the Army to NASA in 1960.[1]

Although each military arm, along with civilian defense contractors, benefited from the Paperclip influx, Air Materiel Command had an unusual preexisting connection to German expertise through two earlier endeavors of the command. Both ties were in the field of civil engineering. As the Army Air Forces initiated a push for an autonomous air arm of the American military (subsequently established as the Air Force in 1947), the service began to address the needs it would face when no longer within the Army. One of the most basic of these concerns was control over the buildings and structures an independent Air Force would require for its expanded operation. By at least 1946, the Air Installations Division at Headquarters Air Materiel Command took on broadened dimensions to

phase out any reliance on district offices of the United States [Army] Engineer (better known as the United States Army Corps of Engineers). Air Installations at Wright Field absorbed the full

> Corps of Engineers services—construction, real estate, and repairs and utilities responsibilities—as well as the master planning program for the future Air Force installation. The success with which the AAF [Army Air Forces] took over these functions was critical to AAF autonomy objectives.[2]

The role of the Air Installations Division within Air Materiel Command during the late 1940s, in particular, appears to have been critical for architectural-engineering achievements of the key commands within the infant Air Force. Two examples were the Strategic Air Command (SAC) hangar for the B-36 designed by Anton Tedesko of Roberts & Schaefer in May 1947, and, the Air Defense Command (ADC) technical buildings designed by Holabird, Root, & Burgee in 1948-1949 (see below).

In effect, from 1946 well into the 1950s, Air Materiel Command operated a civil engineering agency paralleling the Corps of Engineers and given special weight in its relationship to the Headquarters Air Force Directorate of Air Installations (and after 1958, Civil Engineering). The evolving civil engineering expertise was complex, with an emphasis on solving futuristic problem sets and contracting out for renowned engineering expertise—an approach compatible with that for aeronautical R&D post-World War II. Links to major civil engineers were already strong as of 1940 through the contracting of Tedesko for thin-shell, reinforced concrete hangars, shops, and warehouses. The concurrent Army practice of using Austrian, German, Czech, and Hungarian immigrant architects and engineers for assistance in designing target and prototype construction also enhanced connections to the outside civil engineering world. Major German-trained architects deeply involved in World War II Army prototype construction included Eric Mendelsohn, Konrad Wachsmann, and Antonin Raymond—with Mendelsohn additionally taking Army problems to the wider architectural-engineering circles that centered on the "[Walter] Gropius group" at Harvard; Mies van der Rohe and Ludwig Hilberseimer at the Illinois Institute of Technology (IIT); and, Albert Kahn's office in Detroit. With the exception of Kahn, no American counterpart to these men existed for military design efforts.

The interconnections between the German architectural-engineering community and the Army Air Forces were many, becoming especially so as of the middle 1940s. At this time, Wachsmann worked with Hungarian Paul Weidlinger in New York on a patent for a visionary hangar, and by the early 1950s was himself teaching in the engineering department at IIT in Chicago. Norwegian Fred Severud and Austrian Eric Wang were also working in New York during the war, with Severud connected to Kahn and directly assisting the Army Air Forces in new hangar design (see Volume I, Part II). Wang would end up at the University of Cincinnati by the late 1940s and at Air Materiel Command by 1950. Key in all of these interconnections were the Army's joint efforts with the National Defense Research Committee (NDRC). The premier example of an Army-NDRC partnership relying on German-trained architects and engineers was the incendiary bomb test program of 1942-1944. The program featured infrastructure at the Dugway Proving Ground in Utah, on the ranges adjacent to Eglin Field in Florida, and at the Edgewood Arsenal in Maryland.[3] Heavy, reinforced concrete "bombproof" construction was another area of civil engineering study for the Army Air Forces and the NDRC. Work toward protective construction directly involved German civil engineers held for Paperclip as of 1946 and led to Air Materiel Command's study for an underground pilot plant in 1948-1949 (see below). Together, the Army-NDRC work of the war, combined with the highly academic levels of civil engineering expertise filtering into Army design through the hiring of German immigrant architects and engineers, also created significant ties to the

university structure in the Northeast and the upper Midwest. These university affiliations continued after the war, and once again emphasized the broad possibilities of science, engineering, and technology for an air materiel mission. The emerging weapons systems of the early Cold War—particularly biological, chemical, and nuclear weapons—only reinforced the need for the very best R&D, including that for civil engineering.

Theories of the Future

A theory of the future emerged for Air Materiel Command with the first volume in the written studies of Dr. Theodore von Karman, submitted to General Henry H. (Hap) Arnold on 22 August 1945 (Plates 45-46). *Where We Stand* summarized aeronautical scientific progress up through World War II and made predictions about military air power that fundamentally influenced the directions of the command at the outset of the Cold War. Between 1940 and 1945, American military expenditure for R&D had grown from $30 million to $600 million, a 25-fold increase.[4] In the era ahead, Dr. von Karman stated that the Army Air Forces could anticipate:

- aircraft would fly at supersonic speeds;
- unmanned projectiles would carry warheads thousands of miles;
- damage caused by future weapons would be much greater than in the past;
- air defense would entail powerful projectiles capable of seeking targets;
- the fighter control centers of World War II would advance to high levels of sophisticated electronic command and control;
- basic weather and visibility issues would decline in importance as technology advanced; and,
- strategic aircraft forces would be able to strike at distant targets, supported by aerial refueling.

Many of von Karman's pronouncements derived from his analysis of German advancements during World War II. A number of his first recommendations to the Army Air Forces through the Scientific Advisory Group (SAG) relied on adapting German equipment, materiel, test procedure, and expertise to American test installations. For supersonic flight, for example, von Karman recommended wind tunnel testing, beginning where the Germans had left off and constructing subsequent tunnels large enough to contain both aircraft components and scaled full-plane models.[5] "Target Exploitation Briefs" filed by technical team members assessing numerous German manufacturing sites during the summer of 1945 supported von Karman's points of view. In the brief for the Dinglerwerke A.G. at Zweibrücken, team members evaluated the hollow-steel fan blades of the manufacturing site's wind tunnel as innovative. The blades were soon enroute to Wright Field, with accompanying published German professional commentary and photographs from 1937.[6]

Where We Stand represented only Dr. von Karman's preliminary efforts at R&D analysis for aeronautics needs within the future Air Force. Von Karman and a joint team of military men from Wright Field, accompanied by Drs. Frank C. Wattendorf and Hsue-shen Tsien from the California Institute of Technology, left for Great Britain and Europe in late September 1945. As of mid-October, Dr. von Karman settled into writing a more refined document in Paris, and an augmented team of scientific experts continued their information gathering in Asia. General Arnold requested that the SAG team honor the mid-December 1945 submission date for its full study, which the team titled *Toward New Horizons*. The SAG study became the bedrock foundation for a guiding set of theories that would establish a future for the air materiel mission. Twenty-five highly-qualified authors contributed to the 13 volumes of *Toward New Horizons*. The first volume, written by von Karman, was aptly titled for the unfolding of aeronautical R&D during the Cold War: *Science, the Key to Air Supremacy*.[7] Von Karman proposed that science should be interwoven in all aspects of the

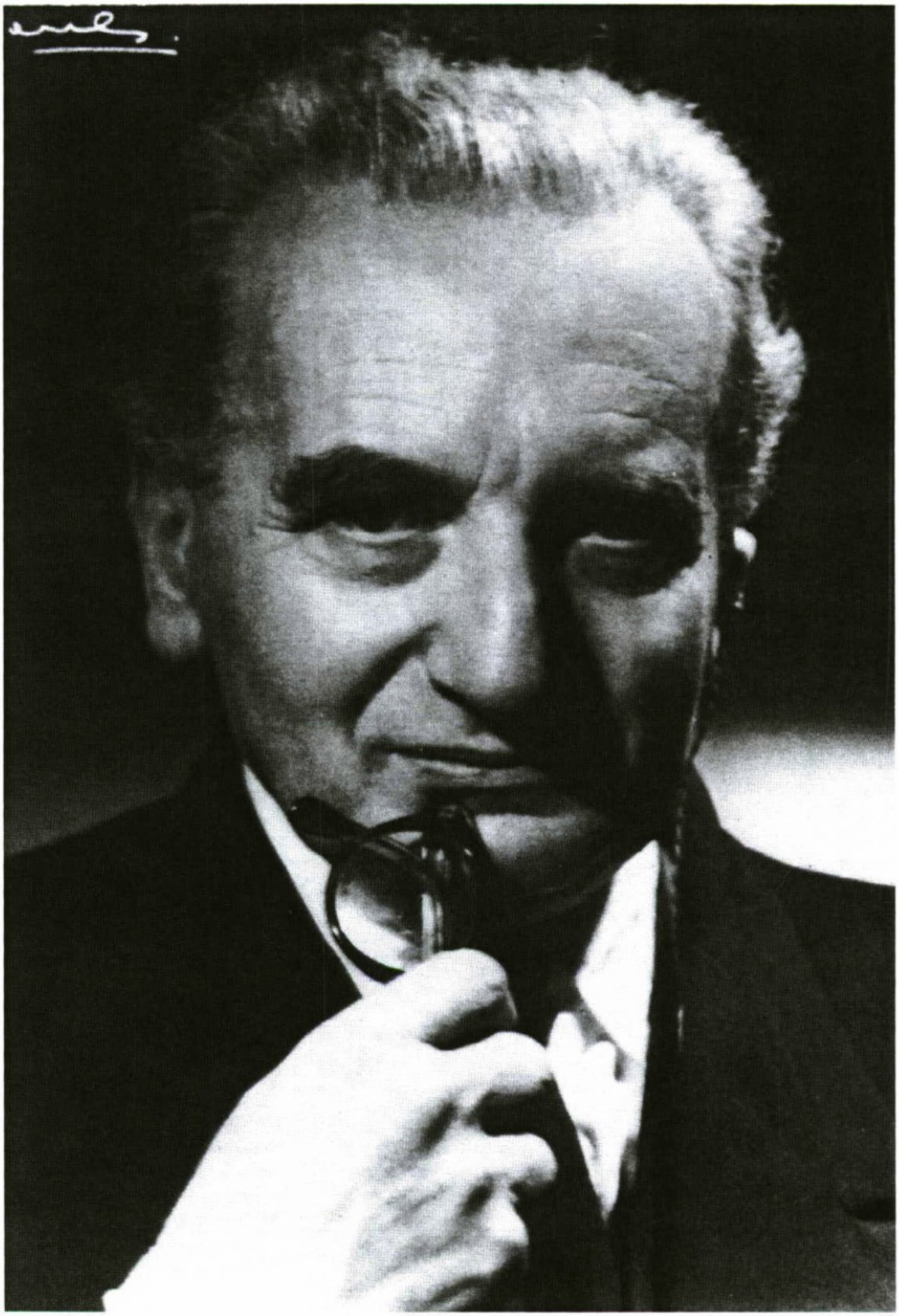

Plate 45: Dr. Theodore von Karman. Undated. Courtesy of the Office of Public Affairs, Arnold Engineering Development Center.

Plate 46: General Henry H. 'Hap' Arnold. Undated. Courtesy of the Office of Public Affairs, Arnold Engineering Development Center.

upcoming independent Air Force, with "complementary technologies" set up at cohesive research centers. He further suggested that the Air Force should encourage research contracts to university scientists, including supportive laboratory facilities, and that the agency should better integrate industry and military aeronautics. For progress in industry, von Karman advocated applied research centers and underwritten pilot plants.[8] Each of these keynote ideas shaped Air Materiel Command during the late 1940s, and helped to define the command's split into Air Research and Development Command (ARDC) and Air Materiel Command at the outset of the 1950s. *Science, the Key to Air Supremacy* also set the stage for the evolution of the standby and government-owned, contractor-operated (GOCO) industrial plant program within Air Materiel Command.

The 13 volumes comprising *Toward New Horizons* foreshadowed the ways in which the Air Force would shape ARDC. The first three volumes were general in their discussions and supportive data. In addition to *Where We Stand* and *Science, the Key to Air Supremacy*, a third volume— the *Technical Intelligence Supplement*—detailed the German achievements of World War II. The remaining 10 volumes each focused on an area of aeronautical research that lay ahead. The first four of these discussed R&D that would subsequently mature in the laboratories at Wright-Patterson in Ohio, at the Arnold Engineering Development Center (AEDC) in Tennessee, and at the Flight Test Center at Edwards Air Force Base in Southern California. The fourth volume, *Aerodynamics and Aircraft Design*, featured three monographic sections written by five authorities serving as a part of SAG. Included were "High Speed Aerodynamics" by Dr. Tsien; "The Airplane—Prospects and Problems" by Dr. William R. Sears of Cornell, Irving L. Ashkenas of Northrop Aircraft, and C.N. Hasert; and, "Aircraft Materials and Structures" by Dr. Nathan M. Newmark of the University of Illinois. Dr. Newmark would have a sustained presence in consulting with ARDC and its follow-on, Air Force Systems Command (AFSC). He became a leading expert in the structural engineering required to protect against nuclear effects (see below). The sixth volume, *Future Airborne Armies*, was a military one, authored by Major Teddy Walkowicz, an Army Air Forces member of SAG. Volume seven, *Aircraft Power Plants*, featured five major sections that analyzed gas turbine propulsion, aeropulse engines, ramjets, solid and liquid fueled rockets, and high-temperature materials. Dr. Tsien wrote the first four of these contributions, while Dr. Pol Duwez, also of the California Institute of Technology, provided the fifth.[9]

The six remaining volumes of *Toward New Horizons* focused on topics that would come of age during the early Cold War years, and through their nuances would stimulate specific air development centers, test centers, and proving grounds within ARDC. Volumes eight and nine of Dr. von Karman's definitive SAG presentation addressed a range of guided missiles issues. In *Guided Missiles and Pilotless Aircraft*, Drs. William H. Pickering and Tsien of the California Institute of Technology, with Drs. Galen B. Schubauer and Hugh L. Dryden of the National Bureau of Standards in Washington, D.C., discussed the present state of guided missiles technology, auto-control, winged aircraft as missiles, and long-range rocket trajectories in vacuums. In 1958, after Congress enacted the National Aeronautics and Space Act, Dr. Dryden became the first Deputy Administrator—second in command—for the new space agency, NASA.[10] In *Guidance and Homing of Missiles and Pilotless Aircraft*, Drs. Dryden, Ivan A. Getting (of the Radiation Laboratories at the Massachusetts Institute of Technology [MIT]), and George A. Morton (of the [David] Sarnoff Research Center in Princeton, New Jersey), presented four monographs evaluating guided missiles in development, heat- and television-guided missiles, missile radar guidance, and radar homing missiles.[11]

Volumes eight and nine of *Toward New Horizons* laid the groundwork for what would become the Cambridge Research Laboratories (Center) at Hanscom Air Force Base outside of Boston and the Rome Laboratories at Griffiss Air Force Base in New York (later, Rome Air Development Center [RADC]), as well as that for the guided missiles proving grounds at the Wendover Bombing and Gunnery Range in Utah; Holloman Air Force Base in New Mexico; and, Eglin and Patrick Air Force

Bases in Florida. Scientists at the MIT Radiation Laboratories had been in active transition during 1945, with those research facilities closing following the end of World War II. Many of these men were in the process of hiring at the Cambridge Field Station of Air Materiel Command's Watson Laboratories at the time of *Toward New Horizons* publication. The Sarnoff Research Center in Princeton had also existed during World War II, established as a Radio Corporation of American (RCA) research laboratory in 1942.[12] Both the MIT Radiation Laboratories and the Sarnoff Research Center pioneered radar research, with additional work in electronics and highly sophisticated sensing devices. By the middle 1950s, the guided missiles mission would be expanded to include long-range missiles, and would include ARDC efforts in Los Angeles and at Vandenberg Air Force Base to its north.

Volume 11 of *Toward New Horizons* also focused on issues of radar and long-range sensing technology, but shifted discussion to the need for an air defense network of interconnected aircraft and ground electronics. In *Radar and Communications*, four scientists analyzed radar sensing and radio communications, with a supplemental analysis of "defense against the atomic bomb." Again, Dr. Morton of the Sarnoff Research Center contributed a monograph. In addition, Drs. Lee A. DuBridge of the California Institute of Technology, and Edward M. Purcell and George E. Valley—both formerly of the MIT Radiation Laboratories and as of 1945 teaching at Harvard and MIT, respectively—presented analyses. These men co-authored the two remaining sections of the volume.[13] Dr. Valley would go on to be key in the developments leading to the Semi-Automatic Ground Environment (SAGE) system of computerized command and control for American air defense of the late 1950s. Also recognized in the DuBridge, Purcell, and Valley discussions was the need for passive protection against atomic weapons in any command-and-control network. Although primitive, civil engineering toward this end occurred as of the first Cold War command posts, directly overseen through Air Materiel Command (see below and Volume I, Part IV). The laboratories at Hanscom and Griffiss would support the air defense missions of ARDC and ADC as of the early 1950s.

Volume 12 in the *Toward New Horizons* series was most directly linked to R&D that would soon be underway at the Cambridge Research Laboratories at Hanscom Air Force Base. Written by only one scientist, Dr. Irving P. Krick of the California Institute of Technology, *Weather* addressed climatic research tied to air power and the conquest of space.[14] Efforts toward all-weather research had been steady within Air Materiel Command and its predecessors back to the beginnings of World War II. The very first Army Air Forces facilities were those of the Ice Research Base in Minneapolis; Ladd Field near Fairbanks, Alaska; and, the climatic hangar at Eglin. The Army also operated a smaller cold room for tank testing at a Midwestern installation as of 1943.[15] The Ice Research Base, at the University of Minnesota, was an ancillary Arctic unit to the Arctic, Desert and Tropic Information Center, set up at Eglin in 1942-1943 as a precursor to the climatic hangar.[16] *Weather*, however, argued for multiple new test sites for Air Materiel Command during 1945-1949. Immediately after the war, weather physics studies went forward at the Clinton County Airfield in Wilmington, Ohio, with laboratory efforts at Wright-Patterson. Outdoor cold-weather testing continued at Ladd, with full-scale, controlled testing underway in the climatic hangar at Eglin. By 1950 and into mid-decade, weather test sites for the command expanded again with the Climatic Projects Laboratory on Mount Washington, New Hampshire, and the Aeronautical Ice Research Laboratory (later renamed the All-Weather Test Station) at Willow Run (Ypsilanti), Michigan. Civilian weather studies on Mount Washington had dated to 1850. More directly pertinent to Army research of World War II, a scientific weather observatory had been established on the mountain in 1932. Mount Washington is only of average height, at 6,288 feet, but offers a premier location for weather science: three weather systems converge on the peak, creating extreme cold, ice fog, and strong winds similar to those of Antarctica.[17] The Cambridge Research Laboratories (Center) at Hanscom also oversaw highly sophisticated efforts toward upper-air (or high-altitude) testing as of the 1950s, with its Upper Air Research Station established on Sacramento Peak, New Mexico. The Cambridge Research

Laboratories sustained complementary tests at Holloman and Eglin through upper-air packages launched atop the Aerobee-series of guided missiles. Finally, the importance of extreme hot and dry weather testing, as discussed in *Weather*, encouraged the Cambridge Research Laboratories to set up an Actinic Test Site in Las Cruces, New Mexico, to study the effects of high intensity solar radiation (ultraviolet light rays) and to experiment under desert conditions in Eglin's climatic hangar.

The two final volumes in *Toward New Horizons* addressed armament science and aviation medicine. Volume 10, *Explosives and Terminal Ballistics*, featured three monographs. Drs. George A. Gamow of Johns Hopkins University in Baltimore and Duncan P. MacDougall of the Naval Ordnance Laboratory in Washington, D.C., explored high explosives, while Dr. Newmark summarized ballistics and destructive effects—paralleling his presentation in volume seven on the characteristics of structural materials.[18] ARDC and its follow-on, AFSC, would focus on armament testing for the Cold War period at Eglin and its associated ranges, eventually as the Armament Test and Development Center. Armament laboratory direction remained at Wright-Patterson, as it had been from the beginnings of the command, while specialized ballistics testing shifted to the Special Weapons Center (and later, Laboratory) at Kirtland Air Force Base in Albuquerque. Additional ballistics experimentation would occur on the ranges associated with Hill Air Force Base in Utah and at multiple, isolated test sites in New Mexico. In the concluding thirteenth volume of the series, *Aviation Medicine and Psychology*, Dr. W. Randolph Lovelace II, M.D., director of the Lovelace Foundation for Medical Education and Research in Albuquerque, and Dr. Charles W. Bray of Princeton University, explored the future of aviation medicine and psychological research.[19] Prior to work on SAG, Dr. Lovelace had helped to develop a high-altitude mask for pilots while at the Mayo Clinic in Minnesota in 1938 and had served as a colonel during World War II at the Wright Aeromedical Laboratory.[20] Dr. Lovelace went on to have a distinguished career in aerospace medicine. The Lovelace Foundation was a basic science laboratory and supported work in biomedicine toward manned space flight. NASA appointed Dr. Lovelace to head its Special Committee on Life Sciences in late 1958. In 1959, the Lovelace Foundation and Clinic tested 32 pilots from Edwards for selection as possible NASA astronauts in Project Mercury—simultaneously also supporting ARDC in its emerging studies for man-in-space. The Lovelace Foundation worked closely with the Aerospace Medical Laboratory at Wright-Patterson and NASA's Langley Research Center as the process continued.[21] Aerospace medicine would develop into a defined ARDC / AFSC research center by the early 1960s, at Brooks Air Force Base in San Antonio. The Brooks facility continued a 1930s School of Aviation Medicine at neighboring Randolph Air Force Base—where a large group of German aeromedical doctors, imported through Project Paperclip, would work as of the late 1940s. While the aerospace medical center at Brooks looked backward to German achievements of World War II, the center primarily looked forward to an Air Force research partnership with NASA in Houston.

The work of Dr. von Karman and SAG not only shaped the ARDC of the 1950s forward, but also led to the establishment of a permanent scientific advisory body, the Scientific Advisory Board (SAB) in July 1946. From this important step came the Ridenour Committee of 1949. Chaired by Dean Louis N. Ridenour of the University of Illinois, the Ridenour Committee evaluated the full spectrum of Air Force R&D organization. By 1950, the Air Force tentatively established ARDC (first as Research and Development Command [RDC]). ARDC represented much that had been observed through German aeronautical successes of World War II, and climaxed predictions of the future present in *Toward New Horizons*. During the first five years of the SAB, 48 distinguished scientists and engineers served on technology panels that reflected individual volumes in *Toward New Horizons*. These SAB panels addressed eight major areas:

- general aircraft;
- fuels and propulsion;

- guided missiles and pilotless aircraft;
- explosives and armament;
- electronics and communications;
- geophysical (upper atmospheric) research;
- aerospace medicine; and,
- the social sciences.

Only the final panel crossed between the boundaries of the earlier monographic presentations.[22]

As the 1950s unfolded, both the SAB and ARDC established themselves as central to Air Force scientific achievement. Nearly simultaneously with *Toward New Horizons*, General Arnold had secured funding for an aeronautical industry think tank, RAND (Research ANd Development), through Douglas Aircraft. By 1948, RAND was an independent, nonprofit organization funded through the Air Force and located in Southern California. RAND's first project report, *Preliminary Design of an Experimental World-Circling Space Ship*, addressed the feasibility of satellites by 1952.[23] As of 1950, R&D within the Department of Defense had grown to $650 million; by 1953, the expenditure climbed to $1,700 million. Combined government and industry R&D rose to $5.4 billion in 1953.[24] Dr. von Karman stepped down as chairman of the SAB in January 1955, moving on to head a parallel international group of European and American scientists to serve as a North Atlantic Treaty Organization (NATO) Advisory Group for Aeronautical Research and Development (AGARD). While ARDC had invited von Karman to update the blueprint-like effort of *Toward New Horizons* as of 1953, a second look at theoretical structuring for future aeronautics waited until 1957. By this date, government and industry R&D had doubled from the expenditures of 1953—to $10 billion.[25] Lieutenant General Thomas S. Power, commander of ARDC, once more asked Dr. von Karman to chair the long-range R&D forecasting endeavor. Von Karman suggested that ARDC attempt the study outside the SAB, through a contract vehicle with the National Academy of Sciences. The late 1950s assessment was to predict Air Force needs in science, engineering, and technology 10 to 25 years into the future.

The National Academy of Sciences contacted eminent scientists and engineers, recruiting a balanced group from academia, government, and industry. The Academy also sought to work closely with the SAB and the National Advisory Committee for Aeronautics (NACA), NASA's long-standing precursor. The scientists gathered at Woods Hole, Massachusetts, during the summers of 1957 and 1958, producing *The Woods Hole Summer Study, 1957 / 1958*. The Woods Hole study reached far more broadly into the university world than had the SAB previously. Over 300 individuals contributed to the National Academy of Sciences two-year effort, with nearly 200 attending sessions at Woods Hole. Another 105 scientists and engineers served as consultants. Timing for the report of the 1957 Woods Hole sessions, however, was not auspicious. The group had not addressed questions of artificial space satellites, although a few scientists (including von Karman) had wanted to do so. When the Soviet Union successfully launched Sputnik in early October 1957, the Woods Hole report of the summer became obsolescent. The Woods Hole scientists and engineers had concentrated on ballistic missiles, as had ARDC during this period. Skipping over satellite issues led to the embarrassment of omitted critical analysis. The project did continue, nonetheless. About 70 scientists and engineers reconvened at Woods Hole during June-August 1958. Military technological applications to space dominated the agenda.[26]

The launching of Sputnik created an atmosphere of ambivalence at the 1958 Woods Hole meeting, with ARDC and the National Academy of Sciences, as well as Dr. von Karman, in general disagreement about the size of a space research program within aeronautical R&D. A lack of consensus fragmented arguments and opinions. Important recommendations about advancing Cold War needs all demonstrated the unflagging need for continuous scientific advancement within the Air

Force. Under discussion was hardening against nuclear effects; an antiballistic missiles system; improved radar and communications in air defense; and, manned high-flyover and satellite reconnaissance. Yet, the 1957-1958 *Woods Hole Summer Study* was not as influential as *Toward New Horizons*. A first-era of Cold War efforts was closing as 1960 approached. The euphoria of the World War II victories was missing, and in fact Woods Hole was a derivative effort rather than a truly innovative one.[27] The breadth of vision was simply not comparable to that present in *Toward New Horizons*. Coupled with the events of the late 1950s, the lackluster qualities of the Woods Hole endeavor helped the Air Force to move toward an R&D more closely held in the hands of military scientists and engineers. (For example, the Air Force had spent only 15 percent of its appropriated R&D funding for fiscal year [FY] 1958 within its own facilities.[28]) The National Security Council's Gaither Report also encouraged the new direction. The Gaither Report announced that the Soviet Union might be capable of a first-strike intercontinental ballistic missile (ICBM) strike by 1959. In the middle 1950s, the percentage of officers trained in science, engineering, and technology had hit a low of 2.7 percent of the total Air Force, a situation not much improved by 1960 when the figure climbed to 3.6 percent. Only during the 1960s, particularly after the reorganization from ARDC to AFSC in 1961, did the figure grow: 6.3 percent in 1965; 6.9 percent in 1970; 7.2 percent in 1980; and, 9.1 percent in 1985. Not until the end of the Vietnam War did the numbers drop somewhat, to 6.2 percent in 1975. The internal R&D establishment of the Air Force post-1961 accepted contracted advice from universities and industry, but retained the ultimate responsibility for its translation into military requirements.[29]

Theoretical forecasting documents for Air Force R&D continued, encouraged by ARDC's commander at the time of transition toward AFSC, General Bernard A. Schriever. General Schriever shaped AFSC as a weapons-acquisition command, and established miniature SABs to evaluate the future. The recommendations of these Division Advisory Groups led to a request in early 1963 to review technologies planned for the future and to predict Air Force scientific, engineering, and technological needs into the middle 1970s. *Project Forecast*, of 1964, involved nearly 500 experts, with a balance between military and civilian R&D opinions. *Project Forecast* recommended the development of small-scale nuclear weapons and materiel to fight limited wars such as that underway in Vietnam. Unlike the *Woods Hole Summer Study*, *Project Forecast* was highly influential in shaping Air Force R&D, becoming a milestone of planning for the future. *Forecast* was a 25-volume study, comprehensive in breadth and depth, with each volume addressing a key component of military-aeronautical science. In late 1974, the Air Force again sought an updated model for its R&D. By this date, efforts became entirely military, with very minimal participation by civilian scientists and the SAB. The middle 1970s study, *Toward New Horizons II*, reflected the see-saw pattern of Air Force R&D assessments. Again derivative and without a comprehensive methodology, *Toward New Horizons II* of 1975 had minimal influence. A final, late Cold War blueprint for future R&D appeared a decade later. *Forecast II*, an internal AFSC document of 1986, was the provenance of military scientists, with most working within the AFSC laboratory framework. AFSC did not consult the SAB until after the command had completed the plan. While comprehensive in style, *Forecast II* moved completely away from Dr. von Karman's advice to involve and rely upon academic science and engineering.[30] Under this approach, the Cold War ended. The cycles of futuristic theory for Air Force R&D had shadowed the periods of confidence, military buildups, and successes of the nearly 50-year Cold War, with the more comprehensive efforts of 1945, 1964, and 1986 those that sustained impact. The complexities and fears of the late 1950s, as well as the difficulties following the Vietnam War in the middle 1970s, helped to destine those efforts for obscurity.

The Role of the German Scientists

As of April 1945, the very large German scientific and engineering establishment represented a prize much sought by the Americans, the British, the French, and the Russians.[31] German achievements of the 1930-1945 period were many. Allied forces sought the well-trained, knowledgeable men, as well

as their equipment and technical documents—both as set up at distinct German R&D sites and as interwoven into German industry, government, and universities. Through multiple code-named operations and projects, the American military and its contractors began to remove men, documents, and equipment to the United States. As early as 1944, Army officials had shipped parts of the V-1 to Wright Field for analysis. By the end of the year, the British and American military agreed that some type of exploitation of German expertise was advisable, with their joint preliminary efforts known as the Eclipse Plan. The next American steps toward German exploitation were the State Department's Project Safehaven and the War Department's Alsos Mission. The overall exploitation program featured two goals: control of research within Germany, and, removal of German scientists and engineers to the United States.[32] Sequential projects went forward. Project Overcast (a recruiting mission) and Operation Mesa (an intelligence effort) both dovetailed with Dr. von Karman's first information-gathering trip to northern Europe and the Soviet Union of May-July 1945. In early June, an interagency conference on the "Exploitation of German Scientists" took place, with discussions continuing into Jly. Talking points at this stage included:

- bringing only "essential" specialists to the United States;
- minimizing their numbers;
- assuring that stays would be "temporary;" and,
- avoiding the inclusion of "known or alleged war criminals."[33]

With the war still ongoing in Asia, much positioning occurred. Many scientists and engineers moved into the American-occupied zone in Germany. The American military set up detention camps in Germany and France to hold more than 1,500 high-level men. Some locations supported large numbers of scientists and engineers, while representatives of the United States tailored others to concentrate men sought specifically by the Navy or by the Army Air Forces. As of late July 1945, the Joint Chiefs of Staff announced an American intent to bring approximately 350 men to the United States to aid in winning the war in the Pacific. The men were to be volunteers, contracted to the United States government. From the beginning, interest in the development of guided missiles was strong. First plans were to have the contracted Germans stay at the Aberdeen Proving Ground in Maryland. As exploitation evolved, the needs of aeronautical R&D would dominant Army Air Forces (and then, Air Force) placement of recruited scientists and engineers. During autumn 1945, key events happened nearly simultaneously. Dr. von Karman submitted *Where We Stand* in late August; the war ended in Japan in early September; American intelligence officers offered scientists and engineers contracts in Germany; von Karman returned to Europe in late September; and, by the end of the month, 11 scientists arrived in the United States on a three-month interim contract—led by Wernher von Braun from the rocket test center at Peenemünde. Four of the men also represented the Aerodynamics Ballistics Research Station at Kochel, including Dr. Gerhard W. Braun. While the initial work was at Aberdeen, six men soon went to Wright Field (see below), with the remaining five relocating to Fort Bliss in El Paso. The latter stationing was in proximity to the missile test range at White Sands Proving Ground, New Mexico.[34] Between late July and November 1945, selected German prisoners of war supported the first scientists and engineers at their American stations. At Wright Field, Major Arthur W. Curtis requested 35 prisoners of war to "act as technical translators (25) and cooks (10)."[35]

From the beginning, lack of a clear policy toward the Germans created challenges and opportunities. In mid-October 1945, Dr. von Karman pointed out that temporary assignment to the United States might not encourage the level of contribution sought, and that the men would then "return to Germany with new knowledge obtained in the U.S."[36] By the spring of 1946, the British announced their intentions of a long-term exploitation of German expertise, which resulted in a parallel American plan under the name Project Paperclip. The complicated process of finding, screening, and working out agreements with prospective scientists and engineers, including the arrangement of their

living conditions in Germany and subsequently in the United States, occupied much of 1946. During this period Germans also slowly began to arrive in the United States. By September 1946, the President formally approved Paperclip. The long-term exploitation effort allowed for family members to accompany the recruited men, although this part of the process was typically slow. Exploitation offered a maximum salary of up to $10,000 per year.[37] With these changes in the program, an initial projection of 350 scientists and engineers increased to one of 1,000. The federal government drafted a new contract for long-term employment as of January 1947.[38] Immediately before this date, the government had additionally expanded Paperclip to allow the exploitation of scientists for "purely civil research" through the Department of Commerce. The policy augmentation would become pertinent to an Air Materiel Command methodology of R&D interwoven with university and private-sector contracting. As of 1947, procedures required coordination between the War, Navy, and Commerce Departments. The requests of Air Materiel Command, while subsumed under the Army Air Forces within the War Department, overlapped with requests through the Department of Commerce for the civilian-operated industrial plants.[39]

Manufacturers made formal inquiries to Wright Field as early as September 1945, asking for the loan of specific German engineers not yet in the United States. One illustrative example was that of the AiResearch Manufacturing Company of Los Angeles. Dr. von Karman had advised AiResearch to acquire a Mr. Jendraseik, former General Manager of the Ganz Company in Budapest, Hungary, and an expert on gas turbines. Von Karman had also recommended that AiResearch recruit Dr. Enke, a renowned German scientist with expertise in the same area. Wright Field deflected such preliminary requests, but placement of both engineers and scientists inside defense contractors' facilities would soon become an active part of Paperclip.[40] The British developed a parallel program of exploiting German scientists and engineers within private industry under the name the Darwin Panel. Focused entirely on aircraft plants, the Darwin Panel employed 15 German scientists and engineers as of late September 1946. Germans working more broadly in industry totaled 27. The British government assigned these men to the Ordnance and Tank Corps, the Admiralty, and the Royal Air Force (RAF). One example of plant activity of this type was the Vickers Armstrong shipyard, where Germans contributed to the design and engineering of new submarine hulls. A key stipulation of the overall program was that advancements made through the exploited Germans were not to be given to the Americans. The no-exchange clause implied a survival of the fittest, as well as a level of private-sector competition. Even so, a sharing of information gained by government-employed Germans, both in the United States and in Britain, was in effect at the outset of the post-World War II programs.[41]

Among the three federal departments, the War Department was quickest to establish a formal policy to implement Paperclip. As a result, the first agencies to use the program were the Army Air Forces at Wright Field and the Army Service Forces at Fort Bliss. The Engineering Division of Air Technical Service Command (and as of March 1946, Air Materiel Command) had received significant amounts of captured German equipment as of spring 1945 and strongly desired to acquire scientists, engineers, and technicians to participate in its reassembly, test, and improvement.[42] As of July, the Engineering Division was busy formulating a mechanism for the dissemination of German technical knowledge. The first plans were for a "seminar program," wherein Germans would lecture on preset topics to gatherings of Army personnel, contractors, and university researchers. Initial topics were "supersonic wind tunnels and supersonic flow;" "high-speed aerodynamics;" "aerodynamics of nacelles;" "rockets and rocket fuels;" "jet propulsion;" "gas turbines and related equipment;" "hot wire apparatus and air flow instruments;" and, "weapons and armament equipment."[43] The Engineering Division planned to have bilingual translators transcribe the lectures, with the events followed by round-table discussions and visits to the appropriate Wright Field laboratories.

By September 1945, immediately before the arrival of the first Paperclippers, the change to the T system affected planning at Wright Field, with both T-2 (Intelligence) and T-3 (Engineering) assigned key roles for related activities at the installation. T-2 took over the Technical Seminar Unit and set up an Air Documents Division. Illustrative of more coordination between Britain and the United States, the Air Documents Division was a result of the transfer of the Air Documents Research Center from London to Wright Field. With the new role of T-2, the intelligence function grew in importance. Security tightened and Wright Field scrapped the planned seminar program. In lieu of seminars, Air Technical Service Command directly assigned arriving Paperclippers to specific laboratories. After a period, the command evaluated their work and granted "industrial interviews." Air Technical Service Command also allowed interviews for "outside agencies as long as they held active AAF contracts and secrecy agreements." The Foreign Exploitation Section of T-2 scheduled the industry interviews and kept close records. In March 1946, the Curtiss-Wright Corporation requested and received permission for the very first such interview of German scientists and engineers at Wright Field. By mid-year, T-2 expanded the industry interview program, allowing sessions for agencies without Army Air Forces contracts. Aircraft manufacturers, research laboratories, and universities were enthusiastic about the program. As of August, T-2 had granted 156 interviews at Wright Field: 83 with private-sector representatives and 73 with laboratory personnel at Wright Field. Companies included Lockheed, Westinghouse, Ranger, Republic, Douglas, Allison, and Thompson Products, while the University of Illinois was an early academic participant. Air Materiel Command also permitted Paperclippers to present four lectures at the Electronics Symposium of July 1946.[44]

Twenty-three German scientists and engineers arrived to work at Wright Field between 18-20 September and the close of 1945. The men came predominantly (and, possibly entirely) in two groups, the first by airplane with Dr. von Braun in September, and another by ship in mid-November.[45] The vanguard group for the Army Air Forces included Otto Bock, Dr. Gerhard Braun, Dr. Rudolf Edse, Dr. Wolfgang Noeggerath, Hans Rister, and Dr. Theodor Zobel. (Dr. von Braun and the four other rocket specialists traveling in September went on to Fort Bliss for the Ordnance Rocket Development Division.) A second group of 17 November included Dr. Rudolph M. Ammann, Dr. Gottfried M. Arnold, Dr. Phillipp von Doepp, Dr. Ernst R.G. Eckert, Dr. Heinz Fischer, Dr. Anselm Franz, Dr. Bernhard Goethert, Dr. Rudolf Hermann, Dr. Wunibald Kamm, Dr. Franz Neugebauer, Dr. Albert K. Patin, Dr. Eugen Ryschkewitsch, Dr. Heinz E. Schmitt, and Dr. Friedrich [Fritz?] Weinig. Three additional men arrived either with the November group or arrived at some date between that of the vanguard and mid-December: Karl Baur, Dr. F. N. Scheubel, and Andreas Sebald.[46] This first group of German scientists and engineers at Wright Field was somewhat fluid. For example, early in the program the Navy made exchanges for Dr. Braun and wind tunnel equipment, also acquiring Dr. Noeggrath.

The Paperclippers who arrived at Wright Field during autumn 1945 included a number of prominent individuals. Three men had worked at the Hermann Göring Institute during World War II: Eckert, Noeggerath, and Zobel. Dr. Eckert had been a jet fuel and thermodynamics specialist there,[47] while Dr. Noeggerath had performed as a rocket fuel expert. Dr. Zobel had been an aerodynamics engineer at the institute, known for the development of an interferometer that measured air flow around models in high-speed wind tunnels. Industry engineers from Germany in this first group at Wright Field included Dr. Ammann, formerly of the Bavarian Motor Works (BMW); Dr. Franz, formerly chief engineer at Junkers Aircraft; and, Dr. Neugebauer, formerly chief of aerodynamics at Messerschmitt. Dr. Neugebauer was also a specialist in power plants, as was Dr. Kamm. Another industrialist in the group was Dr. Patin, an expert in potentiometers for jet engines. Wind tunnel specialists included von Doepp, Goethert, and Hermann. Of note, Dr. Hermann had collaborated on the V-2 project. Aerodynamics experts were Dr. Braun (motor research) and Dr. Weinig (turbines), while Dr. Heinz Fischer was a renowned physicist and specialist in rocket engines. Dr. Ryschkewitsch offered

unusual expertise in carbides and high-temperature ceramics. The remaining men brought expertise in supersonics (Arnold and Bock), rocket fuels (Edse), jet engines (Schmitt), and aerodynamics (Rister).[48] Paperclippers continued to arrive in the United States steadily during 1946 and into 1947-1948. By mid-February 1947, Air Materiel Command had assigned 37 Germans to the Equipment Section at Wright Field, and another 38 to the Aircraft Section. An undisclosed number of German scientists also worked directly for T-2 in intelligence. The command allocated specific men to laboratory assignments that would evolve toward sustained work at Wright-Patterson and toward planned off-site R&D installations.[49]

By mid-May 1947, 148 German scientists and engineers worked for Air Materiel Command.[50] Of these, the command stationed 121 men and one woman at Wright Field. Air Materiel Command placed five men directly in industry and one at a university. The command loaned Heinrich Albers, Herman Bottenhorn, Gerhard Krause, Dr. Ernst Kugel, and Hermann Nehlsen to Loewy Hydropress, Inc., in New York, while Dr. Claus Aschenbrenner went to work at the Optical Research Laboratory at Boston University. Previously, Dr. Kugel and his assistants had designed the large hydraulic forge presses in Germany for light-metals extrusion. At Hydropress, Inc., they classified and catalogued 35,000 drawings of the presses for use by the Army Air Forces and the light-metal industry—the assignment presumably related to the command's proving ground plant in Adrian, Michigan, of this same period (see Volume I, Part II). At the Optical Research Laboratory, Dr. Aschenbrenner assisted in the development of aerial camera lenses. The remaining two Paperclippers assigned to the command worked in Germany: Josef Schugt at the Hermann Göring Institute in Brunswick and Christof Soestmeyer at the BMW plant in Munich. After 1939, BMW had produced long-range bombers. The company tested jet and rocket engines as of 1944 (see Volume II, Chapter 1). Most of the men were in their 30s and early 40s, with selected experts in their 50s and early 60s. A few scientists and engineers were in their middle 20s. Those men placed at Loewy Hydropress and Boston University were among the most senior.

The group at Wright Field as of this date still included all but four of the 23 men present before the end of 1945, and thus represented an influx of 103 new Paperclippers. (Several men may also have come and gone during the 17 months between January 1946 and mid-May 1947. This group is difficult to confirm, but did include at least Georg Rickhey. Mr. Rickhey was the former director of Mittelwerke, the V-2 underground production plant near Nordhausen. See discussion in the section entitled "An Underground Pilot Plant for Air Materiel Command, below.) No longer at any American military installation were Karl Baur, Dr. Scheubel, and Andreas Sebald. Dr. Noeggerath had moved to the Naval Ordnance Laboratory in White Oak, Maryland.[51] Added were Heinrich Adenstedt, Gerhard E. Aichinger, Hans Amtmann, Dr. Adolf Baeumker, Otto Erich Balje, Heinz Beer, Emil Benz, Rudi Berndt, Dr. Walther Boccius, Heinrich Bost, August Bringewald, Dr. Bruno Bruckmann, Willi Buehring, Dr. Wilhelm Buessem, Kurt Danielis, Guenther Dellmeier, Max Dieckmann, Bernhard Dirksen, Friedrich von Doblhoff, Hans-Ulrich Eckert, Kurt Erfurth, Heinz Fornoff, Paul Foerster, Karl Fuechsel, Dr. Otto Gauer, Erich Gienapp, Lambert Graulich, Reinhold Gross, Erich Groth, Dr. Karl Gottfried Guderley, Dr. Otto Harr, Dr. Friedrich Hartung, Siegfried Hasinger, Alfons Hegele, Hans Heinrich, Dr. Helmut Heinrich, Ulrich Henschke, Dr. Albrecht Herzog, Mathias Hickertz, Dr. Sighard Hoerner, Siegfried Hoh, Leo Horres, Franz Huber, Albrecht Hussmann, Willibald Jentschke, Peter Kappus, Rudolf Kassner, Dr. Wolfram Kerris, Dr. Charlotte Kitzinger, Georg Klingler, Dr. Theodor Knacke, Wilheim Knackstedt, Walter Knecht, Eugen Knoernschild, Hermann Koehl, Axel Kolb, Dr. Gunther Krawinkel, Willi Laendle, Heinrich Matt, Hans Mauch, Dr. Hans Mayer, Ludwig Mayer, Dr. Willy Merte, Ferdinand Mirus, Heinz Mueller, Dr. Werner von der Nuell, Dr. Hans Joachaim Pabst von Ohain, Dr. Fritz Penzig, Dr. Johannes Plendl, Dr. Karl Pohlhausen, Johannes Polte, Herbert Raabe, Dr. Werner Rambauske, Heinrich Ramm, Heinrich Reindorf, Heinz Richter, Franz Georg Rinecker, Mr. Rister, Arnold Ritter, Herbert Rosin, Dr. Theodor Rossmann, Franz Ruf, Martin Ruhnke, Hans Sauerland, Wolfdietrich Schaffeld, Helmut

Schelp, Henry Seeler, Dietrich Singelmann, Erich Soehngen, Kurt Staiger, Gustav Strohmeier, Dr. Otmar Stuetzer, Dr. Friedrich Vilbig, Dr. Richard Vogt, Dr. Woldemar Voigt, Karl Volk, Dr. Otto Walchner, Emil Walk, Fredrick Wazelt, Dr. Berthold Weber, Norman Willich, Dr. Bodo [Max] Wolffram, Dr. Rolf Wundt, Hans Ziebarth, and Josef [Sepp] Zott.[52]

Among the new men were many scientists and engineers from the German military policy, R&D, and production centers of World War II, as well as more representatives from German industry and their research laboratories. From the former were Voigt from the German Air Force Ministry; Gauer from the Aeromedical Institute in Berlin and the Physiological Institute at the University of Göttigen; Herzog and Plendl from the Ernst Lecher Institute in Stuttgart; von der Nuell and Schelp from the German Experimental Institute for Flying; Rossmann, former director of the weapons laboratory at the Hermann Göring Institute; and, Walchner from the Aerodynamics Research Institute in Göttigen. From German companies, Air Materiel Command acquired Aichinger, Heinrich and Knacke from the Graf Zeppelin Research Establishment in Stuttgart; Bruckmann and Kappus from BMW, with Bruckmann the former director of the company's plant in Munich and Kappus the former project chief for rocket engines; Dr. Mayer, the former director of the Siemens and Halske research laboratories; Merte from Zeiss Optical Works; von Ohain from Heinkel-Hirth; Penzig, the former chief engineer at the Technical Testing Laboratory of I.G. Farben in Ludwigshafen; Rambauske from Askania Werke; and, Vogt from Blohm and Voss. These men also brought distinguished existing contributions to the command. The three men from Graf Zeppelin were co-inventors of the ribbon-type parachute. (Other parachute experts among the Paperclippers at Wright Field in May 1947 included Berndt, Gross, and Hegele.) Dr. von Ohain had designed Germany's first jet engine, the Heinkel S-1. Dr. Rambauske had developed a television homing device for rockets, while Dr. Mayer was known for his work with acoustic homing devices. Dr. Vogt had designed the airframe for the Messerschmitt 262, the world's first turbojet-powered fighter aircraft to enter combat and had invented the BV-246 glide bomb, while Dr. Walchner had conducted major research toward swept-back wings and had worked on the V-3. Yet another inventor in the group was Mr. von Doblhoff, responsible for the tip-jet powered rotor for helicopters.

Specialized knowledge among the large group was more encompassing than had been true in 1945. One individual, Dr. Baeumker, was known for his expertise in "air facilities." Dr. Baeumker would write a detailed report analyzing German air research development and test centers from 1907 through World War II in June 1951, including both the command structure within the German military for directly operated facilities and for the indirect management of private industrial plants. His report, *German Experience Concerning the Operation of Government Facilities by Private Companies and Non-Profit Institutions*, reviewed the R&D centers and companies from whence the Paperclippers derived, and recommended a solidly government-structured endeavor.[53] Dr. Boccius brought knowledge in structural design and stress analysis; Drs. Buessem and Weber added to Dr. Ryschkewitsch's expertise in high-temperature ceramics, as did Mr. Soehngen. Dr. Pohlhausen and Mr. Singelmann worked on gyroscopes and guided missiles; Mr. Fornoff, remote control systems; Mr. Richter, Mr. Ruhnke, and Mr. Sauerland, automatic controls; and, Mr. Mueller, rocket engines and bomb sights. Mr. Willich, assisted by Mr. Beer, Mr. Koehl, and Mr. Wazelt, brought the capability to translate German research on heat transfer systems. Drs. Guderley and Pohlhausen were advanced mathematicians. Applicable to what would become the AEDC in Tennessee were the talents of Mr. Koehl and Mr. Hickertz in gas turbines; Dr. Hartung and Mr. Volk in hydroelectric technology; Dr. Guderley, Mr. Ramm, and Mr. Matt in transonics; and, Mr. Kolb in aerodynamics. Wind tunnel and supersonics professionals who would remain at Wright-Patterson included Mr. Dellmeier, Mr. Eckert, Mr. Hoh, Mr. Knackstedt, Mr. Walchner, and Mr. Walk. Additional expertise in turbines included the knowledge and experience brought by Mr. Adenstedt, Mr. Balje, Mr. Graulich, and Mr. Horres. Other aeronautics areas also benefited with the influx of Paperclippers. Dr. Stuetzer was a prominent radar expert. Mr. Mayer and Mr. Schaffeld worked with

magnetrons, vacuum tubes that generated extremely short radio waves. Mr. Foerster was an expert in interferometers, instruments that used light rays to measure extremely small distances; Mr. Knecht, an expert on x-ray tubes. High-altitude and ionosphere specialists included Dr. Plendl, Mr. Seeler (aeromedicine), and Dr. Vilbig. Drs. Plendl and Vilbig would work at the Cambridge Research Laboratories (Center) in the years to come, as would Dr. Fischer from the first group of Paperclippers of 1945. Aeromedical professionals arriving at Wright Field between the outset of 1946 and mid-1947 represented yet another specialty, with Dr. Kitzinger the single female Paperclipper among the 122 Germans verified as at Wright Field by this date.

Rome Field, New York, also hosted Paperclippers during the months before mid-1947. Unlike what one might assume, Rome did not represent a first attempt to incorporate Paperclippers at an off-site R&D facility, but rather served as a holding location for scientists and engineers that the command considered excess.[54] Men sent to Rome were either enroute for permanent return to Germany or for release to other American services outside the Army Air Forces—particularly through the Department of Commerce.[55] As of late March 1947, Air Materiel Command identified 37 scientists for transfer to Rome, with additional men anticipated. The command planned housing in Rome for 50 scientists. T-2 described the isolation of these Paperclippers primarily as a security matter. The Rome stationing for these men was

> to prevent them from having further access to classified Research and Development projects now that their exploitation has been completed. It is felt that their presence at Wright Field and contact with other German specialists working on classified projects would give them information that might be detrimental to the national interest should the specialists be returned to Germany.

As of May 1947, 18 scientists resided at Rome Field. Their number dwindled to five by mid-November, with plans to phase out the small final group.[56] This particular Rome assignment lends further credence to a nickname for Paperclip that circulated among the German scientists and engineers themselves: Project Icebox. Most of the highly educated Germans felt that the American government was deliberately underusing their talents. Dr. Joachim Muehlner, working at Holloman in New Mexico, later commented for a written questionnaire: "The feeling prevailed that we had been put on ice—to be cooled off and possibly sent back to Germany." The March 1947 to spring 1948 stationing of Paperclippers in Rome for isolation reasons—a site with winters that could be compared to those of Siberia—certainly supplements the imagery of an "icebox."[57] Somewhat ironically, as of April 1948, the Rome location did support an exempted R&D installation for electronics activities under Air Materiel Command, at Griffiss Air Force Base. The establishment of what would become the RADC dovetailed with the completion of the installation's first, quite different post-World War II role for Project Paperclip.

At the close of 1947, 120 scientists and engineers worked in the Engineering Division at Wright Field, with another 33 Paperclippers assigned to Intelligence.[58] The latter group, in particular, was in a state of change.

> Some of [the Paperclippers] were recommended for continued use in the Intelligence Department because of their unusual linguistic or other abilities which made them particularly valuable on intelligence work. Others had research abilities or abilities of a general nature which were not required by any of the laboratories. Their abilities were such that they would be of great value to the Research Group which was being planned for establishment within the Engineering

> Division. As a part of the new research group, these specialists could work on basic problems of general interest, and they would be available for consultations with the laboratories and with Air Force contractors. It was recommended that as many of the specialists [Paperclippers] as possible of those whose abilities were not fully utilized at Wright Field be allotted to contractors for long-term utilization at the contractors' plants.[59]

The planned dispersal of Paperclippers from the Intelligence Division correlated with the evolution of R&D within Air Materiel Command toward the separate ARDC of 1950 forward. The shift also pointed toward the movement of selected Paperclippers to off-site research and test installations as of the early 1950s. By early 1948, with more Paperclippers continuing to arrive, German scientists and engineers at Wright Field were working in their distinctive realms of expertise. The laboratories divided up the Paperclippers as aeromedical (21), aircraft (8), armament (11), components and systems (3), electronics (6), equipment (23), engineering plans (17), materials (3), parachute (9), photographic (3), power plant (8), and wind tunnels (8).[60] Looking back at compiled lists from February-May 1947, nine of the men working in engineering plans were also specifically assigned to the preliminary planning efforts toward the Arnold Engineering Development Center—at this date more generically titled the Air Engineering Development Center (AEDC).[61] Assigned to developing the AEDC were Drs. Hartung, Hermann, and Arnold, Mr. Ramm, Mr. Dellmeier, Mr. Eckert, Mr. Hoh, Mr. Volk, and Mr. Walk, although several of these men would remain at Wright-Patterson, as noted above.[62] Air Materiel Command was quick to comment that all of the Paperclippers were "outstanding in their respective scientific and engineering fields;" that "American technicians had had little or no experience" in the arenas required by the emerging Cold War; and, that these men allowed the Air Force "to begin where the German research stopped rather than spending Government funds to repeat what had already been accomplished or had been found to be unfeasible." As of December 1947, the command assigned the Paperclippers working in Intelligence at Wright Field to discrete areas of expertise: administration (1); aircraft (1); air documents (1); electronics (11); equipment (6); and, propulsion (13).[63]

Between late 1945 and mid-December 1947, 208 Paperclippers worked under the direct jurisdiction of Air Materiel Command.[64] Numbers continued to fluctuate, with 184 scientists and engineers under the command's umbrella as of early 1948. By the end of 1948, 171 German scientists and engineers worked for Air Materiel Command, with 148 of these individuals at Wright-Patterson.[65] By comparison, as of late 1947 the Army rocket test group at Fort Bliss had climbed to 130 scientists and engineers.[66] In total, the Army had 177 Paperclippers working for the agency as of May 1948; the Navy, 72. About 50 were under the jurisdiction of the Department of Commerce at this same time.[67] More significant than the number of German personnel, however, was their increasingly widespread assignment as of the close of 1947. While the same five Paperclippers continued to work for the Loewy Hydropress Company in New York, those at the Optical Research Institute of Boston University increased by two, with the addition of Drs. Joos and Merte to that station. Georg Joos, like Dr. Merte, had worked at the Zeiss Optical Works in Jena. His colleagues recognized him as an international leader in atomic physics and infrared spectroscopy.[68] Other industry and academic temporary duty stations (TDY) attached to Air Materiel Command included ones for Hubert Nerwin with Graflex, Inc., in Rochester, New York; Walter Riedel with North American Aviation in Los Angeles; Mr. Doblhoff with McDonnell Aircraft in St. Louis; Mr. Graulich, Mr. Koehl, and Mr. Willich with the Detroit Broach Company in Detroit; Dr. von der Nuell at AiResearch in Los Angeles; Mr. Dirksen, Dr. Hartung, Max Schilhansl, and Mr. Volk with Sverdrup & Parcel in St. Louis; Dr. Edse (and Oskar Heil, by mid-March 1948) at Ohio State University in Columbus; and, Dr. Mayer at Cornell University in Ithaca, New York. Dr. Schilhansl shifted from a TDY assignment with Sverdrup & Parcel to one at Brown University in Providence, Rhode Island by mid-June 1948.[69]

Again, the fluidity between stationing at Wright Field and TDY assignments off site with the Air Force, industry, and university is striking from late 1946 through 1947. Mr. Von Doblhoff had previously been on loan by Air Materiel Command to General Electric to work on the XR-17 helicopter power plant during September-October 1946, and then to McDonnell by November that same year for work on "his helicopter."[70] These examples were sporadic, but noteworthy. Sometimes individuals worked on specific industrial contracts at Wright Field, rather than traveling to the plant location. Mr. Ramm did this for Goodyear Aircraft due to the provisional nature of his Paperclip contract in December 1946, even though Akron was in regional proximity to Dayton.[71] (See Volume I, Part II.) Of the group assigned to Sverdrup & Parcel, Air Materiel Command had identified Mr. Volk as working on engineering for the AEDC as of mid-February 1947. Sverdrup & Parcel handled all of the preliminary location studies for the engineering center, as well as its final development near Tullahoma, Tennessee.[72]

As of late December 1947 and throughout 1948, the first off-site R&D installations attached to Air Materiel Command were coalescing. By 15 December 1947, the command had assigned three Paperclippers to the Watson Laboratories in Red Bank, New Jersey: Drs. Max Diem, Heinz Lettau, and Rudolf Penndorf. These men were relatively new recruits, who had not worked for Air Materiel Command before May that year. For the Cambridge Field Station in Boston, the command stationed Dr. Plendl, Siegfried Reiger, and Dr. Hans Zschirndt. Both Drs. Plendl and Zschirndt had been leaders in electronics and radar development at the Lecher during the war.[73] With the exception of Johannes Plendl, these Paperclippers were also with the command only after mid-year. Plendl was a more senior Paperclipper, at 46 years of age in 1947.[74] As of mid-March 1948, Air Materiel Command maintained the Watson- and Cambridge-assigned German scientists at status quo, but added Dr. Wolfgang Pfister the next month at the New Jersey laboratory.[75] Dr. Pfister had arrived under the jurisdiction of the command during the second half of 1947. The increase in Paperclippers at the off-site R&D installations continued slowly in May and July, with the transfer of Drs. Fischer and Vilbig to Cambridge.[76] Fischer, 42 years of age and a specialist in infra-red radiation, was an early Paperclipper for the command who had arrived in November 1945. Vilbig was 44, in place at Wright Field as of March 1947.[77] During 1948, too, those Paperclippers working in Intelligence continued to assist in understanding "technical intelligence on aeronautical research and development trends in foreign countries." The men assigned to the Air Documents Division completed the initial stages of the "Index project," with the express purpose of making documents available to other commands within the Air Force, to American universities and science laboratories, and to the aviation industry. Called a "research tool," the Index catalogued and analyzed "more than a decade of the intensified German aeronautical research and development program." As repeatedly noted, the Index saved invaluable money and time for aeronautical R&D.[78]

A nucleus of German scientists also became established for aeromedicine. By the early 1960s, the aeromedical R&D installation for ARDC / AFSC would be firmly set up at Brooks Air Force Base in San Antonio. Long before this date however, a cohesive group of aeromedical specialists was in place for the command, predominantly staffed through Project Paperclip. Aeromedicine, developed from German expertise, was a distinct endeavor from autumn 1945 forward. The United States Strategic Air Forces in Europe set up an Aeromedical Center in Heidelberg, renaming the existing Kaiser Wilhelm Institute for this purpose. The Army Air Forces operated it as an R&D installation between September 1945 and October 1946, with formal deactivation only as of mid-March 1947. During those months, Air Materiel Command reached out with a long arm to complete 35 German research projects "concerned with biophysical, physiological, and psychological aspects of aviation medicine" in Heidelberg. The operation ended only when a dispute between the United States and the Soviet Union over interpretation of the Allied Control Authority Public Law No. 25 caused its closure.[79] At the Heidelberg Aeromedical Center, the Army Air Forces constructed a German-designed low pressure chamber; ran scientific seminars and lectures; and, translated and published

captured German illustrated aeromedical documents. The agency also solidified academic exchange with the Universities of Heidelberg and Göttingen, and with the Physiological Institute at the University of Berlin. While the center was active, about 200 United States military personnel visited on official business, with more than 300 American and Allied visitors overall. Dr. von Karman inspected both laboratory and intelligence facilities at the site.

In March 1946, German scientific staff at the Heidelberg Aeromedical Center included 18 individuals: Dr. Becker-Freyseng, Dr. Helmut Beinert, Dr. Theodor Benzinger, Dr. Heinrich Bose, Dr. Otto Gauer, Dr. Siegfried J. Gerathewohl, Dr. Heinz Haber, Karl Hausser, Dr. Ulrich Henschke, Dr. U. Kitzinger, Dr. Heinz Maier-Leibnitz, Hans Mauch, Dr. Werner K. Noell, Dr. Siegfried Ruff, Dr. Konrad Schaefer, Dr. Ingeborg Schmidt, Henry Seeler, and Dr. Hubertus Strughold. As of 30 September 1946, the staff had expanded to 23 permanent and temporary scientific staff, with another 10 German doctors working at the affiliated Helmholtz Institute in Berlin. Added doctors were Abraham G.A. Bingel, Konrad Buettner, Wilhelm Ernsthausen, Ernst Franks, Hans May, Hans Oestreicher, Josef P. Pichotka, Johannes W. Prast, Paul Rambacher, Kurt Reissmannn, Kurt Schmeisser, Helmut E. Sieg, Hugo Spatz, and Wolf-Wito von Wittern. One known later addition to the staff at Heidelberg was Dr. Heinrich W. Rose. The total number of German medical professionals gathered together at Heidelberg and Helmholtz by late 1946 appears to have climbed to about 50 men and women (see below). Areas of aeromedical experimentation at the Heidelberg center included the use of seat catapults, color blindness, foreign objects in the eye, sudden thrust acceleration, internal thermoreceptors, measurement of rapid body heat loss and gain, tissue survival with oxygen loss, oxygen poisoning, oxygen equipment, vein collapse, the bends, night vision, improved aircraft controls and panels (optimal colors), prostheses, multiple psychological tests, the effects of glare, blood pressure and flow, and ultra sound measurements.[80] With the closure of the Aeromedical Center in Heidelberg, the Air Force brought a large contingent of German aeromedical specialists to the United States. Twenty-six doctors and technicians working in Heidelberg and at the Helmholtz affiliate went with Dr. Strughold to Randolph Field in San Antonio,[81] where the Air Force School of Aviation Medicine had existed from 1931. Most of the remainder of the group shipped out to Wright Field. One, Dr. Theodor Hannes Benzinger, went to the Naval Medical Research Institute in Bethesda, Maryland.[82]

Eleven scientists and affiliated engineers came to Wright Field from Heidelberg by May 1947, including Dr. Amtmann, Mr. Benz, Mr. Buehring, Dr. Gauer, Mr. Gienapp, Dr. Henschke, Dr. Huch (Kitzinger), Mr. Mauch, Mr. Polte, Mr. Seeler, and Mr. Zott (with the five technicians and Dr. Amtmann present at Heidelberg at its closing). Another eight arrived from the Helmholz Institute Branch before the close of the year: Drs. Ernsthausen, Frank, Franke, von Gierke, Herrmann, Oestreicher, Sieg, and von Wittern. Specialties among the group were of note, demonstrating the range of needs at the beginning of the Cold War in aviation medicine. Henschke, Mauch, Zott, Buehring, and Polte worked on a blind flying instrument and a hydraulic artificial limb at Wright Field. Mr. Seeler had been an engineer with the Draeger Works in Germany, responsible for developing oxygen equipment during the war. He continued this work at Wright Field. In 1952, the Institute of the Aeronautical Sciences gave Mr. Seeler its Thurman H. Bane award for his development of a compact, high-altitude resuscitator.[83] Dr. Gauer specialized in problems of acceleration and the human circulatory system. During the first years at Wright-Patterson, he developed a miniature manometer to measure extremely low blood pressures in the body while inside an anti-G (gravitational force) suit—a device that corrected some serious deficiencies of the suit (Plate 47).[84] Mr. Gienapp was a mechanic who handled the x-ray apparatus used in the acceleration experiments. Mr. Benz had served as a highly skilled glass blower in Heidelberg. The center employed his skills in the fabrication of intricate pieces of laboratory equipment. Dr. Amtmann was a former aircraft designer for Blohm and Voss He contributed to the study of the prone position in aircraft. Dr. Hoch-Kitzinger appears to have been the spouse of Dr. U. Kitzinger. She was

Plate 47: German Anti-G Space Suit, 1930s. Courtesy of History Office, Brooks Air Force Base.

responsible for packing up gas analysis equipment, couriering it to Wright Field, and supervising its set up.

Air Materiel Command particularly prized the Helmholz group, also working with the School of Aviation Medicine to draw upon talent and documents there. At Wright Field, the Helmholz doctors initiated a program to study the effects of supersonic vibrations on the human body, a field that the medical profession interpreted as "completely unexplored" in the United States. Dr. Henning E. von Gierke had arrived at Wright Field in late May 1947. During World War II, he completed his doctoral dissertation on noise generation by gas jets and subsequently contributed to German war research. Within ARDC, Dr. von Gierke rose to become the Director of the Bio-dynamics and Bio-engineering Division of the Aerospace Medical Laboratory at Wright-Patterson in 1961.[85] As of late 1947, Paperclippers with backgrounds in aeromedicine at Wright Field fluctuated up to 23, and stabilized at 20.[86] The overall group was somewhat fluid. In addition to the 19 men and women known to have come directly from Heidelberg in early 1947, aeromedical German scientists at Wright Field by December included Willibald Jentschke, Heinz Moellmann, Franz Rinecker, and Erwin Kurt Weise. Mr. Rinecker had actually arrived very early, in August 1946, although is not known to have been affiliated with the Aeromedical Center in Heidelberg.[87] Coordination with the Aviation School of Medicine at Randolph was predictable, illustrated through several examples. In January 1948, the Air Force transferred Dr. Sieg from Wright-Patterson to Randolph, in a permanent change of station. By March, Air Materiel Command had placed Emile Benz there too, on TDY. In a reverse exchange, Dr. Buettner was on loan from Air Training Command at Randolph to Air Materiel Command at Wright-Patterson, returned to the School of Aviation Medicine in early 1948.[88] Before the end of the year, the school held its first panel meeting addressing the challenges of space flight, and in January 1949 formally designated a Department of Space Medicine. Key staff in the new department included Drs. Buettner, Heinz Haber, and Strughold. Dr. Fritz Haber, an aeronautical engineer and brother of Heinz, also joined the department leadership by late 1950. The two Habers published critical space medicine research as a team at Randolph until the mid-decade.[89] Fritz Haber illustrates yet another common scenario among the Paperclippers. His World War II career had been with Junkers Aircraft in Dessau. There he had developed a method of carrying a missile piggyback atop a plane—an idea that would mature much later as NASA's selected transportation between Edwards Air Force Base in Southern California and Cape Canaveral in Florida, to return the shuttle to its launch site. Fritz Haber also led work toward the simulation of a gravity-free environment. He created zero gravity by having an aircraft fly in a figure eight, rollercoaster pattern, a test method later used at Wright-Patterson aboard a KC-135[90] (see Volume I, Part IV).

School of Aviation documents from 1947-1948, coupled with a master list of Paperclippers in the United States as of June 1947,[91] indicate that Drs. Beinert, Bingel (assisted by his wife), Buettner, Gerathewohl, Heinz Haber, Maier-Liebnitz, Noell, Pichotka, Prast, Reissmann, Rose, Schmidt, and Strughold were among the first arrivals at Randolph.[92] Paperclippers associated with the Army Air Forces Aeromedical Center in Heidelberg also appear to have included several prominent German doctors not on the center's staff. The Aeromedical Center had attracted a significant group of German aviation doctors when the Army established it, additionally fostering close communications between the center's medical professionals and other aeromedical specialists in Germany who did not choose to join the staff in Heidelberg. Falling into this category was Dr. Hans Georg Clamann, whose work the Army featured at the center through his writings. Yet another such expert was Dr. Ulrich C. Luft. Additional German aeromedical professionals arriving at Randolph between late January and June 1947 included Hans Bartholomeaus, Ursala Burkhardt, Horst Fleck, Ella Freitag, Kurt Kramer, Oskar Langner, and Jürgen Tonndorf. Translation of medical documents in German, French, Spanish, Italian, and Russian was another high priority begun at the Aeromedical Center in Heidelberg. The Army Air Forces moved this function directly to Randolph by mid-1947. Three translators, employed for the center in Germany, also came to Randolph: Mr. Erwin Buechel,

Miss Tatjana Schmidt (possibly related to Dr. Schmidt), and Miss Hildegard Weiss. Notably, only aeromedicine brought women professionals to the United States through Project Paperclip: Hoch-Kitzinger at Wright Field, and Burkhardt, Freitag, Schmidt, and Weiss at Randolph.

The Heidelberg technical translation team arrived in San Antonio in early February 1947, initiating a strong tradition of aeromedical publication associated with the Army Air Forces / Air Force. They compiled articles and scientific reports on German aeromedicine, leading to a comprehensive two-volume publication: *German Aviation Medicine World War II.* Major General Malcolm C. Grow, Air Surgeon of the United States Strategic Air Forces in Europe and subsequently the first Surgeon General of the Air Force, had ordered the project in July 1946. Fifty-six aeromedical specialists wrote chapters for the volumes, with nearly all of the manuscripts first drafted in German. Translation into English, with appropriate charts and support materials, delayed the publication of the mid-1946 project until spring 1950. Paperclippers at Wright-Patterson known to have contributed articles were Dr. Ernsthausen, Dr. Gauer, Dr. Henschke, Mr. Mauch, Mr. Seeler, and Dr. von Wittern. Those confirmed for Randolph included Drs. Bingel, Buettner, Gerathewohl, Heinz Haber, Kramer, Luft, Noell, Pichotka, Rose, Schmidt, and Strughold. A number of articles in *German Aviation Medicine* appear to have originated from existing German work of the late 1930s and early 1940s, with some authors likely captured by the Soviet Union and working there during the first Cold War years (see Volume II, Chapter 2).[93] Several of the German specialists at Randolph also immediately began publishing in the American *Journal of Aviation Medicine*, a practice coupled from the first with lectures at professional meetings throughout the United States and Canada. In June 1947, the earliest article, by Drs. Rose and Schmidt, even carried its byline as the Army Air Forces Aeromedical Center, Heidelberg—as did a much later article by Dr. Gerathewohl in June 1951.[94] Articles were numerous and sophisticated, continuing into the 1960s. By the latter date, a few of the most important aeromedical Paperclippers—including Drs. Strughold and Clamann—were still leaders in aviation and space medicine when the endeavor moved to the Aerospace Medical Center at Brooks Air Force Base under AFSC (see Volume II, Chapter 2).

By 1950, the exploitation of German scientists and engineers was thoroughly established within Air Materiel Command. A 1949 estimate had accorded more than 90 percent of the Air Force Paperclippers to R&D missions. As of 1951, 148 Paperclippers worked under the jurisdiction of the new ARDC, with 126 situated at Wright-Patterson and the remaining 22 spread across the command's off-site installations and laboratories. Processing of all Air Force Paperclippers—with the exception of the Strughold aeromedical group that had transferred from the Heidelberg Aeromedical Center to the School of Aviation Medicine at Randolph—remained the responsibility of the Air Technical Intelligence Center at Wright-Patterson into 1953. A small number of German scientists continued to work directly in intelligence at that center. As of early 1952, ARDC had Paperclippers at Cambridge, the Air Force Missile Test Center, and at the AEDC in Tennessee.[95] The beginnings of dispersal for the scientists and engineers to the R&D test installations of the command coincided not only with its expanding structure of 1950-1953, but also with one final program to recruit German specialists to the United States. The shift in management of the German scientists and engineers from the Air Technical Intelligence Center to ARDC also precipitated a name change for the overall effort to that of the Alien Scientists Program, although continued reference to Paperclip was commonplace.[96]

As an extension of Paperclip, Project 63 of November 1950 in part responded to world events. With the outbreak of the Korean War the previous June, the Departments of Defense and Commerce both were anxious to acquire all remaining experts, including those senior men still in Germany and the younger generation of engineers not recruited previously. The desire was as much to deny or severely limit the Soviet Union access to expertise, as it was to increase the numbers of men in the United States. In addition, West Germany's eminent status as an independent republic as of 1954 would

foreclose further removal of scientists and engineers. The Air Technical Intelligence Center at Wright-Patterson had tried a "summer scientist" program during 45 days of 1950 as a precursor to approval for Project 63. Through the program, 10 American scientists teaching in American universities went to West Germany and western Europe as temporary hires for the Center to seek information on the aeronautical advances of their Soviet counterparts. The intelligence summer scientist program verified that "foreign scientists...can be exploited best, and in many cases only, by their professional equals."[97] Although Project 63 moved somewhat slowly during 1951, the Air Technical Intelligence Center approved the program with the explicit intent of placing most new German scientists and engineers within ARDC. Other commands within the Air Force, as well as the Army and the Navy, also participated in Project 63.[98] The Center arranged to cover technical and scientific meetings held in West Germany and Europe during 1951, using what the intelligence personnel called Project Stork facilities to expedite attendance by non-governmental American scientists. These latter efforts were of joint interest to not only the Air Force, but also the Central Intelligence Agency (CIA), the State Department, the National Academy of Sciences Research Council, and the Office of Naval Intelligence.[99] The Air Intelligence Technical Center additionally ran other exploitation projects of a parallel intent, concurrent with Project 63. The Returnee Exploitation Group (REG) Liaison Project of November 1952 interrogated "selected scientific German personnel who have returned from Soviet Russia after having worked there for a number of years on research and development projects." Intelligence officials had been microfilming REG files in Germany, where the interrogation took place, since September—forwarding these to the Center at Wright-Patterson for coordination with the ARDC German scientist program there.[100]

Most of the formal activities of Project 63 took place in early 1952, after a slow continued upward climb in Paperclip recruiting throughout 1948-1951. Efforts of the late 1940s most often happened under separately named intelligence projects. At the close of 1947, 480 German scientists and engineers were under contract to the United States. This figure rose to 504 in 1948, to 523 in 1949, and to 530 in 1951.[101] By January 1952, the military agencies were assessing their needs with regard to the upcoming recruitment in West Germany and the American Zone in Austria. A team of six men included three senior Paperclippers from ARDC, with Dr. Ernst Steinhoff at Holloman Air Force Base in New Mexico the single Paperclipper allowed to remain on the team after last-minute decisions in Washington, D.C. ARDC, in its participation in Project 63, argued that the command required 103 scientists and engineers for positions not readily fillable through the American professional market. The team interviewed about 85 German and Austrian experts to meet this goal. Overseas interviewing for Project 63 occurred between 22 February and 21 April 1952, with the final hiring goal for the command settled at 25 to 35 scientists, engineers, and technicians. Actual processing of the Project 63 contracts continued into 1954, with an unexpected continuance through channels within the Federal Republic of Germany (West Germany) even after this date. Between 1952 and 1954, about 30 German scientists and engineers came to the United States per year. By mid-decade, the weapons race expanded to include space, and the German scientist and engineer programs at the missiles test installations (as well as at NACA facilities) grew rapidly. A final formal recruitment in Germany occurred during 1955 and 1956. This effort included a staff member of the Guided Missile Development Division at the Redstone Arsenal in Huntsville, Alabama, on the interview team. Recruiters interviewed nearly 100 German professionals in November 1955, with a second round scheduled for June 1956.[102] Contracting and arrival in the United States did not cease until nearly the close of the 1950s. The American Rocket Society membership lists reflected this situation in 1958: Germans working for the Army Ballistic Missile Agency at the Redstone Arsenal (initially derived from von Braun's group at Fort Bliss) stood at 82; with 92 at Wright-Patterson; 61 at Holloman; and, 82 at the NACA Lewis Flight Propulsion Laboratory in Cleveland.[103]

For the German scientists and engineers, a shift from their special legal status under Project Paperclip to United States citizenship began in 1952, paralleling the emergence of ARDC and its full web of

R&D installations. From this point forward, and particularly as of about 1957, a number of the Paperclippers working within the American military began to leave their converted civil service positions for jobs in the private sector—particularly with companies that were long-established defense contractors or were emerging businesses tied to missiles and space vehicle development. As of April 1951, ARDC continued to sustain 148 German scientists and engineers under its jurisdiction. The figure hovered back and forth during the next several years. In July 1953, the command's Germans stood at 135, with an increase to 153 as of December 1954. Project 63 gains offset incremental losses. Broken out by specific installation within ARDC, the numbers continued to be the highest at Wright-Patterson, but were significantly larger by 1954 at both the Cambridge Research Center at Hanscom Air Force Base in Boston and at the Holloman Air Development Center. In July 1952, 113 Paperclippers worked at Wright-Patterson; 13 at Cambridge; 4 at the AEDC; 4 at Holloman; and 1 at Headquarters ARDC in Baltimore. These figures remained almost stable until 1954. By December that year, there were 92 Paperclippers at Wright-Patterson; 26 at Cambridge; 2 at the AEDC; 3 at the Air Force Missile Test Center at Patrick Air Force Base; 1 at the Air Force Flight Test Center at Edwards Air Force Base; 30 at Holloman; and, 1 at the Baltimore headquarters. The German scientists and engineers continued to represent a wide variety of aeronautical expertise, with the largest proportion of experts working as mechanical engineers, general electronics scientists, and physicists[104] (Plate 48). Expertise was at a high level. As of late autumn 1954, ARDC supported all but 12 of its 155 Paperclippers as GS (General Schedule)-12s and above. More than half of the German scientists and engineers worked as GS-13s (60), GS-14s (24) and GS-15s (3), which was, and remains, a remarkable achievement.[105]

The contributions of German experts continued to shape and define the first major Cold War efforts across the command over the decade of ARDC's life from 1951 to 1962. No fewer than eight ARDC research and test installations incorporated Paperclip, Project 63, and follow-on scientists, engineers, and technicians—with some locations peaking in numbers of these personnel at the outset of the 1950s, and others in the late 1950s and early 1960s. Paperclippers worked at Wright-Patterson, at the Watson Laboratories in New Jersey, at the Cambridge Research Laboratories (later, Center) in downtown Boston and at Hanscom Air Force Base, at the AEDC in Tennessee, at the Missile Test Center at Patrick Air Force Base in Florida, at the Missile Development Center at Holloman Air Force Base and at the Special Weapons Center at Kirtland Air Force Base (both in New Mexico), at the Flight Test Center at Edwards Air Force Base in Southern California, and at the Aerospace Medical Center at Brooks Air Force Base in San Antonio. Evolved from the School of Aviation Medicine at Randolph, the latter center was strongly connected to NASA's space medicine program. Summaries of the 1950s that reflect the participation of the German scientists at the installations off site from Wright-Patterson are incomplete, but are broadly sketched in the following paragraphs.

Watson Laboratories, New Jersey

From mid-September 1947 through April 1948, Air Materiel Command had formally recommended four Paperclippers to the Watson Laboratories in Red Bank, New Jersey: Drs. Max Diem, Heinz Lettau, Rudolf Penndorf, and Wolfgang Pfister. The command forwarded these particular men to Watson (a facility also known at this time as the Atmospheric Laboratory) due to their "broad backgrounds in specific fields of classical meteorology." Dr. Diem had taught at Jena University. He had also worked at the Aerodynamische Versuchsanstalt in Göttingen (the Aerodynamic Research Establishment, where aerodynamics research on ballistics took place) and at the Meteorologisches Institut in Darmstadt (the Meteorological Institute). After World War II, Dr. Diem became the chief of the Meteorologisches Institut at Karlsruhe Technical University for a brief period. Dr. Lettau, with 50 scientific papers to his credit, had previously taught at three German universities and was a member of the German military during the war. Dr. Penndorf had conducted special weather studies for the Luftwaffe at the Geophysical Institute at Leipzig and at the Berlin University.[106] The four

Air Research and Development Command
Project Paperclip Scientists and Engineers
28 October 1954

Specialty	HQ	WADC (Wright – Patterson)	AEDC (Arnold)	CRC (Hanscom)	FTC (Edwards)	MTC (Patrick)	HADC (Holloman)	Total
Research Administrator	1							1
General Scientist		1						1
Physicist		22		22		3	2	49
Mathematician		2					1	3
General Engineer		2			1		1	4
Aeronautical Engineer		14	1				9	24
Flight Test Engineer		2						2
Guided Missile Engineer							1	1
Electronics Engineer		17					12	29
Mechanical Engineer		11					3	14
Structural Engineer			1					1
Material Engineer		1						1
Ceramics Engineer		2						2
Instrument Design Engineer		3						3
Parachute Engineer		2						2
Photographic Engineer		1						1
Metals R&D				4			1	5
Instrument Maker		7						7
Engineer Technician		1						1
Electronics Technician		1						1
Equipment Specialist		1						1
Glass Technician		2						2
Total	**1**	**92**	**2**	**26**	**1**	**3**	**30**	**155**

Plate 48: Paperclip Scientists and Engineers within ARDC on 28 October 1954. Adapted from *History of Air Research and Development Command 1 July – 31 December 1954.*

scientists remained together at the Watson facility through at least mid-May 1948. As of June Dr. Diem was no longer reported to be at Watson, and instead was listed as "released."[107] Some confusion exists that suggests Dr. Diem may have gone to Cambridge for a short time.[108] In November 1948, the command transferred the Geophysical Research Division, including Paperclippers Lettau, Penndorf, and Pfister, from the Watson Laboratories to the Cambridge Field Station in Boston.[109] Thereafter, no German scientists worked at the New Jersey laboratory site. Between autumn 1950 and early 1951, the remaining 400 men at Watson completed a final transfer to the Rome laboratories (RADC) at Griffiss Air Force Base.[110]

Cambridge Research Laboratories (Center)

Air Materiel Command transferred three German scientists and engineers from Wright Field to the Cambridge Field Station in Boston in late October 1947. Dr. Plendl had a long-term contract, while Dr. Zschirnt and engineer Reiger were at first on short-term contract only. The three men initially worked on the Vapograph project, tied to research in precision radar, in the Radio Frequency Components Laboratory. On 7 May 1948, Wright-Patterson next transferred Dr. Fischer to Cambridge, where he began work in the Special Studies Laboratory on infrared background atmospheric and star-tracking experiments. Dr. Fischer also consulted to the Upper Air Laboratory. By 1953, Dr. Fischer was analyzing microwave energy and stars, as a source of reference signals to guide trackers for the Antenna Laboratory.[111] In late June 1948, Dr. Vilbig (Plate 49) arrived from Wright-Patterson and was assigned to the Communications and Relay Laboratory to work on speech compression and analysis. In November 1948, the Cambridge Field Station Paperclippers increased to eight with the transfer of Drs. Lettau, Penndorf, and Pfister from the Watson Laboratories to Boston. Dr. Lettau addressed problems associated with isotropic turbulence. In early 1949, Joachim Kuettner and Eberhard Wahl arrived directly from Germany. Air Materiel Command assigned them to the Base Directorate, Geophysical Research. Dr. Kuettner, by January working within the Atmospheric Analysis Laboratory, continued his pioneering work studying air flow over irregular terrain, as well as experimental investigations of the electrical structure of thunder storms. His signature study of 1950 was the Mountain Wave Project that assessed the implications of airflow over the Sierra Nevada range between California and Nevada.[112] During the war, Dr. Kuettner had also been a flight test engineer for advanced aircraft, including the Messerschmitt Gigant and the manned version of the V-1 missile, and had flown high-altitude sailplanes.[113] As of May 1949, Dr. Wahl joined Dr. Kuettner in the Atmospheric Analysis Laboratory. Dr. Wahl continued his German studies for the laboratory, focused on "symmetry-point" and "periodogram" methods.[114] Dr. Kuettner transferred from the Cambridge Research Center to von Braun's rocket group in Huntsville in 1958. He continued his American career with NASA, as a part of the Marshall Space Flight Center (geographically sited within the Redstone Arsenal), where he directed the Mercury-Redstone and Saturn-Apollo programs. *Life* magazine featured Dr. Kuettner in its October issue of 1960 in an article entitled "First Rocket We Will Ride."[115]

ARDC records indicate that by April 1952, 13 Paperclippers were working at the Cambridge Research Center—a figure expanded to 25 by the end of December 1954. These men are not all accounted for by name, but do appear to include Mr. Ehrenspeck, G. Gassman, Hans Hinteregger, Christian Junge, Hans Kampe, Heinz Kasemir, Guenther Loeser, Hermann Poeverlein, Gerhard H.R. Reisig, Friedrich Votz, H.B. Wackernagel, and Dr. Helmut Weickmann. The dating of the surge of recruits for Cambridge suggests that most of these men were Project 63 hires, with several likely already in the United States and obtained from outside ARDC. Most were also likely younger men, although several are senior recruits. Among the latter were ones listed as "on order" from European Command, or "requested but not ordered," in June 1947. Dr. Kampe, a meteorologist in Salzburg, had been requested in December 1946, allocated to the Signal Corps as of January 1947 (with actual arrival date in the United States undetermined). The Air Corps had also requested, but not ordered,

Plate 49: **Dr. Friedrich Vilbig with E.W. Samson, C.F. Hobbs, H. Feistel, and R.W. Wagner, the Communications and Relay Laboratory, Cambridge Research Laboratories, 1948. In *Unit History Cambridge Field Station 1 July – 31 December 1948*, volume 8, part 1.**

Dr. Weickmann as of September 1947.[116] Among these men, Dr. Weickmann was a prominent geophysicist who had worked at the Deutsche Forschunganstalt für Segelflug (the German Research Establishment for Gliders) in Darmstadt.[117] The Deutsche Forschunganstalt für Segelflug had carried forward important research on the V-1, on the Wasserfall (Waterfall) rocket, and on controlled glide bombs.[118] Dr. Weickmann was subsequently transferred to the Army's Signal Corps radar and electronics test installation at Fort Monmouth, New Jersey, as of about 1955.[119]

In addition to the Paperclippers working directly at the Cambridge Field Station (Research Laboratories / Research Center) during the late 1940s into the middle 1950s, three other men became affiliated with major Air Force research at the installation through Raytheon Corporation in suburban Boston. Chief among these individuals was Dr. Martin Schilling. Raytheon hired him in 1958 from the Redstone Arsenal. Dr. Schilling had been among the first Paperclippers of the autumn of 1945. *Newsweek* had featured Schilling in a December 1946 article intended to diffuse public sentiment rising against the German-scientist program. During World War II, Dr. Schilling had concentrated his talents on the V-2 as an applied physicist. At Raytheon during his nearly 20-year tenure with the company, he participated in the company's experimental achievements in large phased-array radar, as well as in the development of the Hawk, Sparrow, Sidewinder and Patriot missiles.[120] Dr. Schilling encouraged Raytheon in work towards a ballistic missile warning system. Raytheon won the subcontract with Bell Laboratories to develop the traveling wave tube for the prototype multifunction array radar built on the Kwajalein Atoll in the Marshall Islands during the early 1960s. Further work in phased-array radar, directly involving Dr. Schilling, led to Raytheon's contract for the development of the missile site radar (MSR). By the middle 1960s, Dr. Schilling convinced Raytheon to build and demonstrate its own phased-array radar, a 1,300-element, space-fed Ferrite Array Demonstration (FAD) system. The FAD radar positioned Raytheon to win the contract for the Patriot missile in 1967, as well as that for the Cobra Dane large phased-array radar (through the Rome Laboratories) in the early 1970s. Each of these careful steps moved R&D toward the Perimeter Acquisition Vehicle Entry Phased Array Warning System (PAVE PAWS) radars of the 1975-1985 period, a project of the Electronic Systems Division at Hanscom Air Force Base.[121]

At Raytheon, the Paperclip contribution also featured two other individuals, for short periods. First was Dr. Herbert Wagner, chief missile-design engineer for the Henschel Aircraft Company during World War II (including efforts at Henschel's underground plant near Nordhausen manned by slave labor from the adjacent concentration camp). Dr. Wagner was also renowned for his creation of the HS-293, the first German guided missile operational in combat. Like Dr. Schilling, Dr. Wagner was at the top of the American wish list for Paperclippers. Of real note, the Navy had evacuated Dr. Wagner and two of his assistants to the United States well before the war ended with Japan—by mid-May 1945—to work on a classified project for the Navy's Office of Research and Inventions.[122] He ultimately stayed with the Navy as a Paperclipper and worked at Point Mugu near Oxnard, California, until hiring with Raytheon in Boston.[123] The Navy considered Dr. Wagner's expertise "unmatched anywhere in the world." After surrender to Allied forces at Oberammergau at the outset of May 1945, Dr. Wagner had presaged much of what Dr. von Karman would discover about the value of German documents and personnel. He took American Navy officials to the Henschel underground facility; provided boxes of blueprints and models; and, offered plans for his next-era weapon, the radio-controlled antiaircraft rocket Schmetterling (Butterfly).[124] The third Paperclipper hired at Raytheon in Boston was Heinz Mueller.[125] Mr. Mueller had arrived at Wright Field by May 1947. He worked within Air Materiel Command, and subsequently ARDC, as his prelude to Raytheon. His specialty was rocket engines, and like Dr. Schilling, he had been a part of the scientific team at Peenemünde during World War II. The example of Raytheon, focused on its R&D relationship to the Air Force, illustrates the intricate connections between ARDC, its specific installations, and the military contract world.

Rome Air Development Center

When Griffiss Air Force Base became an exempted electronics installation for Air Materiel Command in April 1948, the facility had just completed an interim mission of 1947-1948 as a holding station for Paperclippers being returned to Germany. Decision making for the specifics at Griffiss was slow and by late November 1948, the command transferred the Data Utilization Laboratory (the Visual Design Laboratory) at the Cambridge Research Station to Rome, New York—simultaneous with its move of the Geophysical Research Division from the Watson Laboratories in New Jersey to Cambridge. The Data Utilization Laboratory did not include any German scientists or engineers at this date.[126] Air Materiel Command also planned to move the Base Directorate, Radio Physics Research to Rome from Cambridge as of early 1949, but met with major resistance on the part of its personnel. This portion of a more extensive staff relocation to Rome included both the Radar Laboratory and the Communications and Relay Laboratory. During these organizational discussions of late 1948 into middle 1949, a tentative suggestion to merge Air Materiel Command's facilities at the Watson Laboratories, the Cambridge Field Station, and Griffiss Air Force Base through the development of a single, cohesive air development center at Griffiss also floated at upper Air Force levels. (This course would have maintained only a small field station at Hanscom Air Force Base.) By late July 1948, the Air Force recognized that it would lose most of its valued employees should it shift the electronics and radar test installation wholly to Griffiss, and subsequently decided to develop both Cambridge (at Hanscom) and Griffiss (as an electronics development center). ARDC moved the Technical Library from the Watson Laboratories to Griffiss in early 1951, continuing to divide up the resources and responsibilities of the Watson-Cambridge facilities.[127] Over time, the Rome installation, located on Griffiss Air Force Base, would become ancillary to Cambridge—sometimes as the whole of the RADC and sometimes as individual laboratories. Rome regained a more independent status later in the Cold War.[128] No known Paperclippers worked at the RADC on permanent assignment during the 1950s, but it is likely that some TDY occurred.

Arnold Engineering Development Center

Approximately a dozen verified German scientists, engineers, and technicians worked at the AEDC or, in the later years of the 1960s and 1970s, at the University of Tennessee Space Institute nearby (Plate 50). The initial group of Paperclippers arrived at the AEDC by early 1952 and included four men led by Dr. Bernard Goethert.[129] During World War II, Dr. Goethert had served as the chief engineer for high-speed aerodynamics at the General Research Institute for Aerodynamics in Berlin. He was among the very first Paperclippers to come to the United States, in November 1945. Dr. Goethert was also among the 16 men showcased by the Army in a series of articles appearing in *Newsweek*, *Life*, and the *New York Times* at the close of 1946.[130] As a member of the staff of Arnold Research Organization (ARO), Inc., Dr. Goethert became chief of the Propulsion Wind Tunnel at the AEDC by late 1952. ARO, a special division of Sverdrup & Parcel, was the contractor operating the AEDC.[131] In the middle 1960s, Dr. Goethert served as the chief scientist for AFSC. He also helped to found the University of Tennessee Space Institute at Tullahoma, where he would later teach.[132] Heinrich Matt, Heinrich Ramm, and Gottfried M. Arnold probably moved from Wright-Patterson to the AEDC with Dr. Goethert in 1952. Dr. Arnold and Mr. Ramm had been among the group of nine men who had worked on the conceptual plans for an AEDC while at Wright Field. Dr. Arnold had arrived in the United States with Dr. Goethert in late 1945, and was a research coordinator. Mr. Ramm worked as an aeronautical engineer, assigned to Wright Field as of March 1946. Both men had served with Wernher von Braun's group at Peenemünde.[133] Mr. Matt, Dr. Goethert's chief technical assistant, is the probable fourth member of the original Paperclipper team at the AEDC. He had arrived at Wright Field in October 1946.

Plate 50: Dr. Bernard Goethert (center), with Heinrich Ramm (on his left) and Dr. Hans K. Doetsch (on his right). Bracketing four men, unidentified. 1955. Courtesy of the Office of Public Affairs, Arnold Engineering Development Center.

Among the remaining seven German scientists and engineers associated with the center, Dr. Hans Doetsch was apparently in the United States by 1947, but not under the jurisdiction of Air Materiel Command or ARDC before transferring to the AEDC. Karl Thormaehlen, at Wright Field very early with Dr. Goethert, had been assigned to private industry until arriving at the AEDC in 1956. Otto Bock and Axel Kolb, Hans Rister, and Mathias Hickertz were at Wright Field as of September 1945, October 1946, and July 1946, respectively. Engineers Bock and Rister had been among the small vanguard of Paperclippers accompanying von Braun. These men each later transferred to the AEDC.[134] An undated list of Paperclippers and their families, attached to a letter of July 1948, also notes Hermann Schneider, Alfred Windmueller, and Emil Salmon as working at the AEDC or associated with the center through private industry.[135] Schneider, Windmueller, and Salmon had arrived at Wright Field by mid-December 1947.[136] The final Paperclipper with known ties to the AEDC was Dr. Gerhard Braun, who had worked at Wright Field from the first days of the Paperclippers and had transferred to the Holloman Air Development Center in 1954.[137] Dr. Braun joined the staff of the Space Institute in the late 1960s.[138]

Air Force Missile Test Center

Air Materiel Command assigned one Paperclipper to the Missile Test Center at Patrick as of January 1952, apparently on a short-term project. From April 1952 into at least late 1953, no German scientists or engineers are officially recorded at the installation. By the close of 1954, however, the center had three men assigned whose identities remain unresearched.[139]

Holloman Air Development Center

More German scientists and engineers worked at Holloman Air Force Base by the late 1950s than at any other Air Force location except Wright-Patterson. Holloman benefited initially through its association with the nearby Fort Bliss and White Sands Missile Range. By January 1946, the Army had shipped 83 Paperclippers to Fort Bliss.[140] At this same time, 100 Paperclippers were in place at Wright Field.[141] By mid-1948, the numbers of German scientists and engineers at Fort Bliss reached 130;[142] while at Wright-Patterson, the numbers stood at 170.[143] Air Materiel Command did not officially record Paperclippers at Holloman during the earliest years. As of 1949 however, the Army had loaned Dr. Ernst Steinhoff, Dr. Joachim W. Muehlner, and Werner Gengelbach to the Air Force to conduct instrumentation and facilities-planning surveys for the base. These and other Paperclippers had worked at White Sands testing V-2 rockets as of 1946. ARDC records list four German scientists and engineers at the Holloman Air Development Center by 1952-1953, although through the Army loan process Steinhoff, Muehlner, and Gengelbach worked both at Holloman and White Sands throughout 1949 to 1952. When von Braun's group at Fort Bliss transferred to the new permanent rocket test location in Huntsville in 1950, these three individuals continued at Holloman / White Sands and formed the core of the group that would serve ARDC. In 1952, three new Germans joined them at Holloman. Drs. Helmut Kuerschner and Ernst Lange had been a part of the Fort Bliss group as of 1947, but had moved to the Redstone Arsenal in Huntsville with von Braun in 1950. They next transferred from the Army to the Air Force, returning to test work at Holloman and White Sands. Dr. Kuerschner was an expert in accelerometers; Dr. Lange, in missile wiring.[144] Dr. Herbert T. Lotze, possibly a Project 63 recruit, also arrived in 1952. The group's activities focused on missiles test and development, with Steinhoff, Gengelbach, and Kuerschner having worked together at Peenemünde during the war on problems of rocket inertial guidance and ground control electronics.[145]

Discrepancies arise in the numbers of Paperclippers at Holloman by the end of 1954. ARDC records list 29 men; while 32 are verified as present at the base level. Seven of the 10 leading men possessed doctorates: Steinhoff, Muehlner, Lotze, Gerhard W. Braun (transferred from Wright-Patterson),

Gerhard R. Eber (transferred from the Navy Bureau of Ordnance at White Oak, Maryland), Dr. Martin G. Jaenke, and Dr. Walter K. Jahns. Drs. Braun and Eber were both preeminent men, from the Göring Research Institute in Brunswick and the wind tunnel test operations at Kochel respectively. The Navy had captured the Kochel test site and had requested Dr. Eber among its 111 Paperclippers. Drs. Jaenke and Jahns were Project 63 recruits who arrived in 1953. Each man had been a "priority"-listed target for recruitment as early as 1946. Steinhoff and Eber, in turn, served as chief scientists at Holloman. The others worked in a supervising capacity, although Dr. Muehlner transferred back to the Army. At White Sands, Dr. Muehlner continued an integrated relationship with Holloman. Five of these men were still at Holloman in mid-1959, with civil service grade levels ranging from GS-14 to GS-17. Many of the remaining 22 Germans at Holloman by the close of 1954 were Project 63 engineers, with disciplines including aeronautics, mathematics, electronics, and mechanical engineering. These men were Hans F. Bueckner, Friedrich P. Ehni, Heins F. Gehlhaar, Joachim H. Gengelbach, Hans G. Gschwind, Heinrich A. Heithecker, Fritz Hoehndorf, Hermann A. Kahle, Heinz G. Klose, Herbert Knothe, Karl H. Koellner, Reinhard Krause, Egon E. Muehlner, Herbert K. Neumann, Tassilo Proppe, Gottfried R. Rosenthall, Autur H. Schendel, Heinz T. Schwinge, Werner Spilger, Robert G. Tantzen, Ulrich Tarnowski, and Paul F. von Handel. The exact procedures of the Project 63 efforts remain vague, but one example is that of Tassilo Proppe. Dr. Steinhoff recruited Mr. Proppe in 1952. ARDC brought him to the Missile Test Center at Patrick Air Force Base in 1953 for initial training, sending him on to Holloman in 1954. All of these men were also highly successful in their positions at Holloman. Of those at the base in mid-1959, nine had achieved GS grade levels of 13, 14, and 15.[146]

The Holloman Air Development Center conducted one final recruitment in Germany during 1955-1956, joining with the efforts of the Army's Redstone Arsenal. As of this recruitment and including minor transfers from earlier placement at American military installations, 19 more scientists and engineers arrived at Holloman by the end of 1956: Heinrich W. Englehardt, Karl Erbskorn, Hubert C. Feder, Trutz Foelsche, Friedrich Guenthner, Hans O. Hasse, Rudolf H. Huebel, Frank Keipert, Heinrich J. Penzig, Helmut Reischl, Fritz O. Rossman, Margot Schiedat, Henry J. Schindler, Josef Schneider, Friedrich Utech, Richard Waetjen, Heinrich J. Weigand, Walter E. Woehl, and Hans F. Wuenscher. Heinrich Weigand came from Wright-Patterson, where he had been since late 1947. Guenthner, Penzig, and Rossman were also already in the United States. In 1957, seven more Germans arrived at Holloman, taking the middle 1950s total influx to 26: Hermann F. Borges, Ferdinand Kuhn, Spyro Kyropoulos, Harald Melkus, Hans J. Rasmussen, Hermann O. Scharn, and Guenthner Schindler. Of this group, Melkus was a transferee from another American site. Dr. Kyropoulos was the highly unusual one. A contemporary of Dr. Steinhoff, Dr. Kyropoulous had immigrated to the United States to teach at the California Institute of Technology (with Dr. von Karman) in the mid-1930s, after dismissal from government service under the Nazis.

Holloman continued to gain German recruits even as late as the early 1960s. Drs. Harald J. von Beckh (aviation medicine), Hermann P. Greinel (aeronautical engineer), and Bruno Manz (physicist) arrived in 1958-1959. These men were of the older generation of potential professionals and had served in the German military service during World War II. Two arrived via Argentina. Dr. Manz, a young physicist with a doctorate from the Institute of Technology in Aachen, had first worked for Siemens-Schuckerwerke between 1955 and 1957. The Army recruited him for the Redstone Arsenal in late 1957. From there, he transferred to Holloman in 1959. Dr. von Beckh was an Austrian medical scientist, placed at the 6571st Aeromedical Research Laboratory at Holloman in early 1958. During the late 1950s, this laboratory was a sister facility to the School of Aerospace Medicine at Randolph Air Force Base in San Antonio and to the aeromedical research laboratory at Wright-Patterson (the latter undergoing a series of formal name changes during these years). Dr. von Beckh ran the weightlessness program at Holloman, and rose to director of the laboratory's scientific programs. In Argentina, he had experimented with "tanks of labyrinthectomized water turtles in

fighter aircraft under subgravity conditions." By the early 1960s, Dr. von Beckh headed the Human Factors Division of the Martin Company in Baltimore.[147] Like other aeromedical specialists at Randolph, and subsequently at Brooks, Dr. von Beckh published in the *Journal of Aviation Medicine* (later retitled *Aerospace Medicine*). His articles were printed as early as mid-1954, submitted from Buenos Aires.[148] Available records mention the last recruits only vaguely. At Holloman were Dr. Hans Joachim Gevelhoff, Dr. Dieter Holberg, Guenther Willibald, two mathematicians with doctorates, and several men with bachelors. Exchange between White Sands and Holloman persisted, with Dr. Gevelhoff beginning his assignment there in 1959. The unnamed men came only briefly and quickly returned to Germany. Research materials for Holloman suggest that the total number of Paperclippers and follow-on German recruits was approximately 70 over a 12-year period. The group peaked in about 1957, with a number of the Germans thereafter beginning to leave for private sector jobs, or joining the von Braun group or NASA. Some key individuals also transferred to Kirtland Air Force Base in Albuquerque.[149]

Air Force Special Weapons Center / Laboratory

Absorption of Paperclippers into activities at Kirtland dates to about 1960-1961. By this date, R&D began to shift toward nuclear simulation experiments, and within several years also focused on the missiles mission in cooperation with the Air Force Missile Development Center (the follow-on to the Holloman Air Development Center). As of August 1970, the Air Force Missile Development Center merged with the Special Weapons Center, with missile development continued at the Albuquerque installation.[150] The number of German scientists and engineers at Kirtland appears to have been small, but with several very important men present. Transferring from Holloman to Kirtland were at least three men. The most prestigious was Dr. Gerhard Eber. Dr. Manz also transferred. The third individual was Josef Schneider, who had been recruited to Holloman in 1956.[151] German engineer Ferdinand Kuhn remembers these three men leaving for Kirtland with the Air Force Office of Scientific Research as their assignment.[152] Between January 1960 and July 1970, the Air Force tiered the Office of Scientific Research under the Office of Aerospace Research, rather than under ARDC / AFSC. Most likely the transferees filled research posts within R&D units of the Air Force Special Weapons Center (after 1963, the Air Force Weapons Laboratory [AFWL]).

ARDC acquired the Air Force Special Weapons Center within its umbrella of installations in April 1952. As of September that year, the Special Weapons Center had established a Research Division—the forerunner of the AFWL. The Research Division (later Directorate) focused on Air Force R&D for problems of nuclear and advanced weaponry, including problems of vulnerability and survivability. In mid-1958, the Special Weapons Center created a Physics Division within the Research Directorate to begin weapons simulation studies. The moratorium on nuclear testing announced at the end of October caused the Special Weapons Center to generally staff down. It disbanded its 4950th Test Group (Nuclear) of 1956-1961 and withdrew from its efforts at the Nevada Test Site and the adjacent Indian Springs Air Force Base even while continuing to move forward with simulation test plans. As of early 1959, the Air Force planned for a new nuclear laboratory complex at Kirtland that would be related in mission, but would be distinct from the Special Weapons Center, the Los Alamos and Livermore Radiation Laboratories, and the Sandia Corporation. By late 1961, buildings for the laboratory were under construction while simultaneously the Special Weapons Center staffed up again to increase nuclear test operations in the aftermath of the Soviet atmospheric detonation of a nuclear device in September. Full-scale efforts at the Pacific and Nevada Test Sites occupied 1962 and 1963, until the Limited Nuclear Test Ban Treaty between the United States and the Soviet Union fully redirected the work of the Special Weapons Center toward simulation techniques. AFSC, the follow-on for ARDC, established the AFWL from R&D components of the Special Weapons Center in May 1963. The AFWL concentrated on the simulation of nuclear effects including induced shock, transient radiation, x-rays, and electromagnetic pulses. Within the AFWL

by mid-1963, its Research Division was further divided into Physics, Biophysics, Space Physics, Mathematics, and Structures Branches. AFSC also reoriented the mission of the Special Weapons Center, itself distinct from the AFWL, to support missile development with continued nuclear test responsibilities using advanced simulation expertise.[153]

Air Force Flight Test Center

The number of Paperclippers working at the Flight Test Center at Edwards Air Force Base was very small. ARDC records note one individual there in early 1952. No one was present in mid-1952, with only one Paperclipper there between 1953 and the close of 1954. The early assigned Paperclipper appears to have been Dr. Hans J. Pabst von Ohain, who was possibly joined briefly by Ernst Heinrich Heinkel of the German company Heinkel-Hirth (Plate 51). Dr. von Ohain was 35 when he had arrived at Wright Field in 1947,[154] and was listed as TDY as of August 1948. Von Ohain's time at Edwards may have been only an extended visit. His 30-year career with the Air Force was focused primarily at Wright-Patterson. Wilhelm Buss, a parachute designer for the Luftwaffe during the war, also spent time at Edwards as a Project 63 short-term hire.[155] Sometime during the early 1950s, a final known Paperclipper was associated with Edwards. Dr. Theodor Knacke, at Wright Field as of May 1946, worked for the parachute test facility run by ARDC at El Centro, California. The parachute facility was subsumed under the jurisdiction of Edwards.[156]

Aerospace Medical Center

The Aerospace Medical Center at Brooks Air Force Base was the follow-on to a component of the Aviation School of Medicine at neighboring Randolph. The number of Paperclippers specialized in aeromedicine was large as the space medicine program developed at Randolph during the late 1940s through the 1950s, possibly as high as 40 men and women (see above). While planning for a permanent Aerospace Medical Center at Brooks Field had begun in late 1946, these efforts stalled. Facilities design occurred in early 1951, but a dispute between the hired architectural firm and the Army Corps of Engineers stopped progress a second time. No construction occurred until 1956, and not until mid-1959 did President Lyndon Johnson dedicate the Aerospace Medical Center at Brooks. By this date, very few of the Paperclippers present at Randolph during the late 1940s and early 1950s appear to have made the transfer to Brooks. Paperclippers known to have worked at the Aerospace Medical Center at Brooks include Drs. Hubertus Strughold (Advisor for Research), Hans-Georg Clamann (Chief of the Department of Space Medicine), and Juergen Tonndorf.[157] As of the late 1950s and into the early 1960s, the World War II team had begun to retire, transfer to other agencies, or shift to the private sector. Several examples are illustrative. As of October 1957 (or earlier), Dr. Heinz Haber was on the faculty of the Institute of Transportation and Traffic Engineering at the University of California.[158] By 1960, he was living in Hamburg, Germany.[159] As of November 1958 (or earlier), Dr. Gerathewohl had transferred to the Army Ballistic Missile Agency at Redstone and by early the next year was chief of the bioastronautics research unit there.[160] Several years later, Dr. Gerathewohl worked in the Office of Life Science Program for NASA in Washington, D.C.[161] As of March 1959 (and possibly earlier), Dr. Fritz Haber was working in Stratford, Connecticut. Dr. Buettner was in Seattle.[162] By 1960, Dr. Luft had hired with the Lovelace Foundation in Albuquerque.[163] Perhaps of most interesting note, as of 1963 the aeromedical Paperclippers who remained active from the World War II group had also reintegrated with their colleagues in Germany. In October that year, the German Society for Aviation and Space Medicine, paralleling its American counterpart, held its first annual meeting at the Physiological Institute in Munich. Two hundred professionals attended, including Dr. Strughold from the Aerospace Medical Center at Brooks and Dr. von Beckh from The Martin Company in Baltimore (earlier, Holloman and Redstone). Prominent American Air Force aeromedical professionals also were present, as exemplified by Colonel John Paul Stapp (who spectacularly tested acceleration effects on the high-speed track at Holloman).[164]

Plate 51: Dr. Hans J. Pabst von Ohain (standing), with Ernst Heinrich Heinkel. Undated photograph. Courtesy of the History Office, Edwards Air Force Base.

Special Missions

Also evocative of the influential role of science, engineering, and technology in shaping the Air Force's R&D command at the outset of the Cold War and through its first decades, was the emergence of two special missions. Both represented new problem sets, with the first major strides occurring during World War II and with an escalated focus identifiable during 1944-1945. One of these special missions, biochemical and nuclear weapons, had been primarily orchestrated within the domain of the Army's Chemical Warfare Service and the NDRC during the war. With the cessation of the NDRC in late 1945, the government transferred many of NDRC's active research projects to the Research Board for National Security. After further review, selected former-NDRC projects became those of Air Technical Service Command. The NDRC had relied heavily on contractors, such as university research laboratories and private industry, with significant work in progress toward chemical and biological warfare. Selected experimentation of 1944-1945 on the test ranges at Eglin Field reinforced the Air Force inheritance of NDRC biochemical studies. The rise of atomic, and then thermonuclear, weapons was also tied to what would become ARDC (later AFSC) from the beginning, with links back to the NDRC. The Radiation Laboratories at MIT, which had worked steadfastly toward the accomplishment of the atomic bomb during the early-to-middle 1940s, transferred many of its personnel to the Cambridge Field Station of the Watson Laboratories after the war. The atomic bomb test drop had occurred at the Trinity Site, southeast of Albuquerque and northwest of Alamogordo, in mid-July 1945. The Alamogordo Bombing and Gunnery Range (later, the White Sands Proving Ground and Holloman) and Kirtland Field supported the Trinity tests. Both Kirtland and Holloman Air Force Bases became ARDC installations at the outset of the Cold War. Neighboring Kirtland, the Sandia Laboratories would become home to the Armed Forces Special Weapons Project (AFSWP). Kirtland itself would host the Air Force Special Weapons Center and the AFWL. Each of these organizations focused their missions on the development of nuclear weapons and related phenomena.

The second of the special missions within the Air Force's research command was more subtle and can be defined as a concentrated sequence of efforts toward futuristic civil engineering. From the immediate post-World War II years forward, the civil engineering mission often was directly linked to special weapons. From the beginning, the dominant focus of a special civil engineering mission within ARDC / AFSC was on protective construction of three types: (1) heavy, bomb-proof construction; (2) construction functional against deployed biochemical and atomic weapons; and, (3) highly sophisticated construction hardened in multiple ways against nuclear weapons. Key installations for this latter mission were those of Wright-Patterson (1945-1956) and Kirtland (1956-present), with multiple off-base test sites including the Utah Test and Training Range (UTTR) near Hill Air Force Base as of the middle 1960s. The command's sophisticated civil engineering mission of the Cold War, like that of special weapons, had been an NDRC priority during World War II. Both the special weapons and related sophisticated civil engineering missions sustain large classified components today, and are only discussed here through specific examples of the first Cold War decades. Another broad, but highly important civil engineering mission assigned to ARDC / AFSC was that for prefabricated, shippable infrastructure, from buildings to runways. The two installations most strongly linked to this mission were Wright-Patterson and Eglin, both involved in this endeavor from early World War II forward.

The Biochemical and Nuclear Problem Sets

Among the defining R&D missions of Air Technical Service Command, Air Materiel Command, and ARDC during 1945-1955 was a responsibility for new and powerfully destructive weapons. Although sophisticated nuclear missiles of guided and long-range type would come to represent the pinnacle of technological weapons achievements, the earliest focus was on aircraft-delivered

biological and chemical agents and, by the late 1940s, on developing biological and chemical warheads for guided missiles. American chemical agent testing had existed as of World War I, but R&D toward biological agents was new as of 1940-1941 when Dr. Vannevar Bush asked that the Army formally consider the potential of biological weapons. As of November 1942, buildup toward a biological weapons capability began through the establishment of the Special Projects Division within the Chemical Warfare Service. The Service established a biological agents research center at Camp Detrick in Maryland in April 1943, as well as a biological proving ground on Horn Island off the Gulf Cost near Pascagoula, Mississippi. By late 1943, the Army Air Forces, in conjunction with the Chemical Warfare Service and the NDRC, simultaneously undertook chemical agent tests using tethered animals on the ranges at Eglin and at nearby Florida sites, as well as on the Dugway Proving Ground in Utah. The Air Proving Ground at Eglin also supplied personnel for running the tests at Dugway and at the Edgewood Arsenal / Aberdeen Proving Ground in Maryland. (Edgewood was home to the Chemical Warfare Service.) As of mid-1944, the Chemical Warfare Service also set up biological agents testing on Granite Peak at Dugway.[165]

The Army Air Forces next employed human subjects for chemical agent spray tests at its San Jose Island Proving Ground in the Panama Canal Zone in late 1944 and early 1945, coordinating efforts through Eglin Field. Initially, Eglin's testing expertise focused on developing chemical spray tanks for B-17s, B-24s, B-25s, B-26s, P-39s, and P-40s. Tests at Eglin during late 1943 through 1945 concentrated on jungle warfare, with an emphasis on defoliation of tropical landscapes and incapacitation of entrenched enemy troops, applicable to the war in the Pacific.[166] By September 1943, the Chemical Warfare Service initiated its first airborne weapons experiments and participated in a demonstration of remote-controlled glide bombs and pilotless aircraft at Muroc Field (the future Edwards Air Force Base) in the Southern California desert. The first formal chemical bomb project of the Service followed in January 1944, formally titled "Glide Bombs for Chemical Agents." As of March 1945, the Joint Chiefs of Staff fully supported the development of a chemical bomb program.[167] By 4 September 1945—immediately after the dropping of the two atomic bombs on Japan—the Chemical Warfare Service updated its January 1944 chemical glide bomb project as "Guided Missiles for Chemical Agents."[168] Simultaneously, the first series of JB (jet bomb)-2 guided missile test launches ended at the Eglin test range site of Santa Rosa Island. Three men representing a JB-2 squadron had left for the Philippines in August, with discussions underway to employ the JB-2 against Japan. Plans toward use of the JB-2, as well as possible employment of chemical agents as warheads for guided missiles, collapsed after the Army Air Forces dropped atomic bombs over Japan on 6 and 9 August.[169]

Immediately after the end of World War II, the United States government asserted the position that future weapons of mass destruction would include atomic, biological, and chemical devices, with evolving acronyms first appearing as of late 1945. References to the new triumvirate would include ABC (atomic, biological, and chemical), CBR [also, CEBAR] (chemical, biological, and radiological), AW (atomic warfare), BW (biological warfare), CW (chemical warfare), RW (radiological warfare), and NBC (nuclear, biological, and chemical). The initial post-war stance reduced the efforts toward R&D for chemical and biological agents. Immediately, the Chemical Warfare Service (soon to be Army Chemical Corps) closed the biological-agent Horn Island Proving Ground and placed the Granite Peak site at Dugway on standby.[170] Within a year, however, the government reversed itself. The Army began to experiment with ejectable nose cones (warheads) for the V-2 rocket at the White Sands Proving Ground in New Mexico, a location adjacent to what shortly would become Holloman Air Force Base. High-altitude tests of mid-December 1946 sent a payload of fungus spores aloft using the World War II German rocket.[171] V-2 launches had multiple research goals, with many involving upper atmospheric tests. Scientists at the Cambridge Field Station (later, Research Laboratories) typically ran numerous first experiments addressing the fundamental physics of the upper atmosphere through participation in the V-2 firings at White Sands during 1947 and 1948.[172]

V-2 nose cones sometimes carried sophisticated equipment and at other times functioned as test warheads. The Blossom series of 1947-1951 involved warhead testing using the V-2 at White Sands, with participation of the Cambridge Field Station and Wright-Patterson. Contracted university laboratories ran tests during particular Blossom launches, as did Air Materiel Command. The Franklin Institute in Boston handled warhead fabrication and assembly, parachute studies, sequencing, and timing controls. The Wentworth Institute, in Boston, also assembled Blossom-series warheads with special packaging and wiring. Oklahoma A&M University conducted the beacon triangulation work for the tests, while Wright-Patterson concentrated on parachute studies.[173]

The Blossom series was geared toward achieving the basics of a viable biological weapon, and is an excellent example of the complex interaction between the Army and the R&D installations of Air Materiel Command / ARDC. The warhead canister of the nose cone ejected from the V-2 at high altitudes and fell back to earth assisted by a parachute. In one test of early 1948, the Blossom III separated from the V-2 at a height of 29.6 miles when the rocket had attained a velocity of 1800 feet per second.[174] The Blossom IV-D launch reached an altitude of 81 miles, with the warhead canister ejected near the zenith. In some cases, the parachutes malfunctioned and the warhead self-destructed upon impact on the ranges of White Sands.[175] The V-2 Blossom launches tested many different parameters of the upper atmosphere that were pertinent to the functioning of a biological warhead traveling in this manner through high altitudes where contents of the warhead would be exposed to direct cosmic radiation unfiltered by the lower atmosphere. X-rays, neutrons, and gamma rays irradiated any payload.[176] Scientists also gathered fundamental information about the upper atmosphere during these launches, a focused mission of Cambridge. Explicit upper-atmosphere experiments were associated with numbered Blossom shots of the V-2 at White Sands. By 1951, the responsibility for the V-2 Blossom launches fell to Holloman Air Force Base in its role within ARDC. The Air Force launched Blossom IV-E from the Army's V-2 complexes at White Sands in March "to measure equivalent electronic density; infrared radiation; and nonlinear effects of the ionosphere, composition and night skyglow."[177]

Through the Research and Development Board jointly staffed by representatives of the Army, Navy, and Army Air Forces, as well as the United States Public Health Service and the Department of Agriculture, the federal government had set up the Committee on BW (Committee X) in January 1947.[178] Most often, biological weapons ranked immediately behind those of atomic weapons. During the late 1940s, the Army Air Forces interpreted biological and chemical weapons as a more likely destructive tool than atomic bombs, which at that juncture were not available in any numbers nor stockpiled in any usable manner. Military science interpreted biological weapons as capable of incapacitating men and animals, ruining crops and disrupting major food sources, and contaminating a physical area for extended periods. While the long-range BW goal was guided missiles with biological warheads, immediate post-World War II efforts also addressed simpler mechanisms. Dissemination through the air suggested not just spray mechanisms, such as those employed for chemical agent testing during World War II, but also the development of small biological bombs that were a follow-on to incendiary bomb testing of the war (also at Eglin and at Dugway). The small BW bombs were thought to be a useful additional weapon to that of atomic warfare. The Army Air Forces planned to create a "ring of BW contamination...completely around the areas affected by the blast, heat, and radiation of an atomic explosion."[179] While the development of biological and chemical weapons predominantly remained an Army program during the late 1940s, the Army Air Forces (and subsequently, the Air Force) established a distinct Air Chemical Office with liaison representatives assigned to the Army Chemical Corps between 1945 and 1948. Through this mechanism, information for the development of biological weapons moved between Camp Detrick and Headquarters Air Force. The Air Force also placed a weather detachment for research in micrometeorology at Detrick—effectively a liaison between the scientists working there and at Cambridge.[180]

While the Army continued experimentation with the V-2 at White Sands, the newly independent Air Force also moved toward BW-CW guided missiles research as of late 1947. The Air Force BW-CW program had originated through the Army's Chemical Warfare Service and the NDRC of World War II. A strong tie to the Army continued after the two military services separated. The Air Force contracted to the Army Chemical Corps to develop the "chemical, incendiary, and supertoxic [biological]" warheads required for its guided missiles, thus effectively segregating R&D for the missiles and their warheads. Incendiary warheads derived from the intensive development of incendiary munitions during the war. The Air Force provided the Army Chemical Corps its specifications for incendiary warheads for the Gapa, Wizard, and Thumper missiles as of December 1947, adding the Firebird and Nativ missiles in 1948. Also in 1948, the Air Force program for guided missiles with special warheads swung into high gear. The Chemical Corps contracted to develop incendiary, chemical, and biological warheads for the Matador, and incendiary and chemical warheads for the Snark and Shrike / Rascal. The Glenn L. Martin Aircraft Company (Martin) contracted with the Air Force to design the missile and with the Army to develop the special warhead. The Matador was an appropriate choice for such concentrated efforts, given Martin's Baltimore proximity to both the Army's Chemical Center at Edgewood and its biological research laboratories at Camp Detrick, both in Maryland, and the soon-to-be headquarters of ARDC in Baltimore.

R&D toward chemical and biological warheads for guided missiles peaked between 1948 and 1953. In September 1948, Air Materiel Command hosted a conference on chemical warheads at Wright-Patterson. During October-November, Martin ran its first nose cone (warhead) drop tests at Holloman. Martin used inert clustered bomblets to simulate the Matador warhead for the drop tests. At this same time, the company also completed its design for a 3,000-pound chemical warhead for the missile, relying on the World War II agents phosgene and cyanogen chloride—both lung irritants. By early spring 1949, discussions were underway at Camp Detrick for a biological warhead for the Matador.[181] Early BW-CW guided missiles experimentation continued at Holloman during 1949 into early 1951, with nose cone drop tests run at Alkali Flats (today within the White Sands Missile Range). The tests used clustered bomblets and are assumed to have employed simulant agent. The majority of the tests appear to have recorded the physical dispersion patterns of the individual small bombs comprising their composite cluster. As of mid-1951, Air Force – Army efforts shifted toward a serious CW Matador, with a sarin gas (GB) warhead. Drop tests for the nose cone of the GB Matador occurred at Holloman a year later.

Actual assignment of the Air Force chemical and biological weapons development mission had gravitated toward Air Materiel Command almost immediately. As of 1948, the functions of the World War II Air Chemical Office became a part of the Directorate of Armament within Air Materiel Command, where the BW-CW mission remained through 1949. While ARDC was in its formative stages during 1950, the Air Force grouped the biological-chemical weapons mission with atomic weapons development at Special Weapons Command. The Air Force established Special Weapons Command at Kirtland Air Force Base in Albuquerque in January. By July, the difficult-to-categorize mission was variously delegated throughout the Air Staff at Headquarters Air Force, only to return to the jurisdiction of Air Materiel Command by late October. The onset of the Korean War further complicated assignment of the BW-CW mission. As of autumn, the Army informed the Secretary of the Air Force that seven BW agents were feasible for use in cluster bombs, including cereal rust spores intended to destroy the winter wheat crops of the Soviet Union.[182] That announcement of 1950 was a reminder that only four years earlier the Army had launched fungus spores in the nose cone of a V-2 at White Sands in testing toward such an outcome. The Air Force programmed an anticrop offensive capability for March 1951 and a BW antipersonnel offensive capability for January 1952. The Air Force also incorporated a sequential atomic-BW capability into the war plans of SAC, with a target capability date of July 1954.[183]

With the establishment of ARDC in 1951, BW-CW R&D fell to the Armament Division of the command. Five of its test installations, in addition to the command's headquarters at Wright-Patterson in Ohio, became associated formally with biological and chemical weapons work of the early 1950s. At Headquarters Air Force, the Air Force Office of Atomic Energy (AFOAT), BW-CW Division, set top secret policies. In 1951 the Air Force did not interpret the Dugway Proving Ground in Utah as having appropriately available aircraft or year-round meteorological conditions to meet agency needs, although it served as the major agents test location for the Army. The Air Force then established a policy that ARDC's test work toward biological and chemical munitions would be explicitly assigned to Eglin, Edwards, and Holloman Air Force Bases. The Armament Test Division at Eglin, evolving into the Armament Center, would be the primary responsible unit. By 1953, the Armament Test Facilities Laboratory at Eglin featured a Bio-Chemical Branch; the Directorate of Test Operations, with a BW-CW unit; and, the 6570th Chemical & Ordnance Test Group, with a BW-CW detachment.[184] Edwards was to be the location for "developmental tests of high speed clusters," while Holloman was to "be utilized for dispersion and fuze functioning tests of BW munitions as well as for tests of chemical warheads for guided missiles." In all three cases—Eglin, Edwards, and, Holloman—previous use of these installations' natural terrains (ranges, vast dry lake bed, and alkali flats) had already occurred.[185] Kirtland continued to play an administrative role in the program, with ties to the atomic weapons program. For high-altitude testing, the Cambridge Research Center sustained a presence in the overall atomic-biological-chemical triumvirate. The Cambridge Research Center was involved in high-altitude tests both at Holloman as of 1947, and at sounding rocket launch complexes on Eglin's Santa Rosa Island as of a decade later. The Wright Air Development Center (WADC) and its predecessors at Wright-Patterson orchestrated varied aspects of agent research. Among the tasks of the WADC was the procurement of refrigerated vans (mobile igloos) for the storage and transport of live agents needed in tests at Eglin in 1953.[186]

By the middle of 1952, the BW-CW Division of AFOAT guided the Air Force biological weapons program toward "a lethal anti-personnel biological munition for release from high speed aircraft and upon the development of munitions for delivery of anti-crop pathogens from high speed aircraft and by balloons."[187] By the close of 1953, priorities had shifted to place the greatest emphasis on developing a usable anthrax (N) bomb, with the interim munitions employing anthrax in a liquid suspension and the final versions using the agent dried. The planned intent by July 1954 was to have developed and tested a "lethal munition-agent combination that could withstand a wide range of meteorological conditions." *Bacillus anthracis* was "relatively rugged and stable, allowing storage for several years in a dry state. Anthrax was also easy to produce in large quantities."[188] Anti-crop munitions studies had gone forward since 1950, but were further accelerated as of 1954. The agent of choice continued to be wheat (red stem) rust spores that were cultivated for military use, harvested under careful conditions, and stored within the jurisdiction of the Ogden Air Materiel Area (AMA) (Hill). Deterioration of this particular agent was high year to year, with new supplies needed to replace aging ones, and storage refrigerated. The wheat rust anti-crop bomb was comprised of clustered small bomblets containing the agent.[189] Key participants in the development of this BW munition were "the [Army] Chemical Corps, WADC, the Air Force Cambridge Research Center...and General Mills Corporation."[190] Air Force plans envisioned that a gondola lifted by a hydrogen-filled balloon would transport five BW containers of rust spores, also carrying ancillary equipment and "an apparatus for neutralizing the agent in the event of forced ejection over friendly territory."[191]

Air Materiel Command's Cambridge Field Station used high-altitude balloons to gather information on events in the upper atmosphere from at least 1949. Selected tests led to the related balloon projects Gopher and Moby Dick of the early 1950s, which in turn were tied to the biological warfare program. In 1949, while the Blossom V-2 experiments were underway at White Sands, the Cambridge Field Station ran a series of balloon-launch tests at Avon Park Air Force Base (bombing range) in Florida in which balloons carried microphones to pick up the air wave effects of bombs

detonated at 20,000 feet altitude, at 400 miles distant. (Presumably the Air Force detonated the bombs over the Eglin ranges.) Similar balloon launches from stations in New Mexico and Arizona carried microphones to record the compressional waves generated by the V-2s launched at White Sands. The intent for both of these launch series was to study the refraction of shock waves, with an ultimate goal of determining the "optimum height of [the] burst of an atom bomb."[192] Balloons also gathered facts for the Cambridge laboratories during atomic detonations at this same time to collect radiation information. In 1950, personnel at Wright-Patterson initiated development for Project Gopher. The Cambridge Research Center took over Project Gopher in May 1953. Gopher was to "carry a 500 pound payload for 14 days, pass over enemy territory without danger of interception, and return to friendly hands." To do this, a balloon would carry reconnaissance equipment across enemy borders at an altitude too high for detection—tunneling invisibly over rather than under terrain, similar to a gopher. By the end of June 1953, work toward Gopher's goals kept a balloon vehicle aloft for just under nine days.[193]

As of mid-May 1951, Headquarters Air Force approved Moby Dick, a project of the Cambridge Research Center to accurately observe wind fields at constant altitudes of 50,000 to 100,000 feet (approximately 10 to 20 miles up) using plastic balloons of 45-, 61-, and 73-foot diameter. Electrical mechanisms minimized the visibility of the balloons' ascents and descents. If a Moby Dick balloon started to descend between 3,000 and 30,000 feet, or if it had not risen above 33,000 feet within two hours, an auto-destruct device terminated the mission by destroying the balloon. Once above 30,000 feet, and in descent, the same mechanism punctured the balloon when it passed beneath the 30,000-foot plateau and lowered the payload to the ground with a 24- or 28-foot parachute.[194] The Air Weather Service (AWS) at Lowry Air Force Base in Colorado provided the centralized plotting for the project, while the Airways and Air Communications Service (AACS) and the Navy supplied very high frequency (VHF) direction-finding stations. The prototype test launchings occurred at Holloman. Participating universities were those of New York University and Tufts. The thin-skinned, polyethylene balloons could support payloads of several hundred pounds. The Cambridge Research Center and Holloman planned the development phase of Moby Dick for 1951 and early 1952, with Holloman then training crews to man three West Coast launch sites (Plate 52) . When underway, Moby Dick would sustain at least nine of the large balloons at a particular selected altitude within the tracking net, simultaneously.[195] The planned number of operational Moby Dick launches from the West Coast was 750.[196]

The Moby Dick program was complex. Operational launches for Moby Dick began in January 1953, with 320 launchings by mid-year. Of the balloons launched, 145 remained aloft for 20 hours or more, while 37 crossed the entire continent during their flights. Others landed in Mexico, Canada, and as far away as Norway and North Africa. The three West Coast operational sites launched an average of two Moby Dick balloons a day. All were remote, with two in California and all likely situated at Navy installations. The first was associated with Edwards Air Force Base, but quite probably was sited at an ancillary facility in El Centro. ARDC operated the Joint Parachute Test Facility with the Navy at the El Centro Naval Auxiliary Air Station during this period, under the ARDC parent structure at Edwards. The El Centro facility, through the 6511th Parachute Development Test Group, explicitly tested "aerial delivery systems for cargo" among its assigned missions.[197] The second California Moby Dick launch site was in Vernalis, at an airfield that had served as another Naval Auxiliary Air Station, tiered to the Naval Air Station in Alameda during World War II. Vernalis sits in the San Joaquin Valley west of Modesto. A third West Coast location took advantage of a Navy World War II dirigible installation at Tillamook, Oregon. By June 1953, ARDC planned to establish two additional Moby Dick launching sites, one at Moody Air Force Base, Georgia, and one at Whiteman (then, Sedalia) Air Force Base, Missouri.[198] As of this date, Moby Dick also served to continue development toward Gopher (keeping a 500-pound payload aloft for 14 days undetected) and supported research for the balloon delivery of a biological munitions package. While Moby Dick was an unclassified endeavor, described several times in *Aviation Week* during 1953, the project

Plate 52: Moby Dick Test of Balloon Launcher at Holloman Air Force Base, 5 June 1952. In *Historical Report Annex No. 1 6540th Missile Test Wing (HAFB) 1 May – 30 June 1952*, volume 2.

"served as a convenient cover" for activities that were not. Balloon vehicles, such as those that Moby Dick tested, were the "object of the munitions delivery program...to carry biological warfare agents over enemy territory."[199]

By 1954, Moby Dick appears to dovetail with ARDC efforts toward a balloon-carried gondola packed with containers of wheat rust spores that functioned as an anti-crop bomb. The anti-crop balloon-bomb, lifted by hydrogen, was to travel in a stable manner at very high altitudes. The Air Force considered the device a strategic weapon, with the AWS and AACS at Lowry in Colorado providing support. The anti-crop bomb project had trained launch personnel already available, with plans for five launch sites. These descriptors also characterized Moby Dick.[200] The Air Force, presumably SAC, must have planned to take over the five Moby Dick operational sites for reuse as manned bio-warfare and reconnaissance launch pads, with three installations in Southern California, one in Georgia, and one in Missouri. Lessons learned from both Moby Dick and Gopher would allow the sophisticated balloons to carry 500 pounds of equipment or munitions thousands of miles over a two-week timeframe. The anti-crop balloon-bomb program also had the hardware for its system in storage at two overseas bases as of 1954, with intent to transport live agent overseas for refrigerated storage (as at the Ogden AMA).[201] The mechanism for Gopher required that after about 14 days the Air Force pick up the balloons, with their missions accomplished, in "friendly territory." While ARDC handled the research, development, and test of the anti-crop balloon-bomb during 1950-1954, Air Materiel Command stepped into the munitions storage and shipment process. Air Materiel Command complained that the "over-all balloon delivery program did not have an AMC [Air Materiel Command] monitor." More doubts arose. During 1955, the Special Weapons Division at Headquarters ARDC in Baltimore concluded that "balloons were not suitable for delivery of biological warfare agents and...[recommended]...that work on all such systems be discontinued."[202]

Serious biological and chemical munitions testing continued throughout the 1950s and 1960s, with many efforts focused at Eglin Air Force Base (testing through the Air Force Armament Center), but with direction from Wright-Patterson (development responsibilities) and support at both Holloman and Edwards at least through the middle 1950s. The Armament Center had responsibility for Phase I-VI BW testing, while Air Proving Ground Command at Eglin conducted the follow-on Phase VII testing for operational suitability.[203] In addition to munitions delivery via guided missiles and balloons, ARDC returned to the late World War II idea of aerial spraying—particularly for chemical-agent weapons that would function as growth inhibitors and defoliants. The Air Force flew C-47s in test trials at Avon Park's ranges in Florida during 1950 and 1951, destroying a "broad-leaf crop." Work continued with aerial spraying into early 1953, with success at up to an altitude of 2,500 feet. ARDC next established a requirement for an aerial defoliant and accompanying spray canister in 1954.[204] Live-agent testing, particularly for biological agents, was almost exclusively done at the Army's Dugway Proving Ground in Utah. However, by mid-1952, the Air Force planned for an alternate "hot-agent" test site. Air Materiel Command assigned Ralph M. Parsons Company the task of evaluating test facilities, and concluded that with improvements, Eglin could provide the range facilities to fulfill this role by about 1958.

> Eglin needed an instrumented testing range, a chemical and biological test laboratory, and the necessary support facilities and services. Funds for a range and assessment laboratory [were] requested in the Air Force fiscal 1956 facility funding program.[205]

Between 1952 and mid-decade, Eglin added a Bio-Chemical Branch at its Armament Test Facilities Laboratory, a BW-CW unit in its Directorate of Operations, and a BW-CW Detachment for the 6570th Chemical & Ordnance Test Group. The Air Force and Army conducted joint suitability tests for antipersonnel agents using concentrated *Brucella Suis*, with logistics managed at Eglin and cluster

bomb drops flown at Dugway. The Army placed 11,000 live guinea pigs in trenches and prefabricated "houses," especially devised for the tests. Live testing of animal viruses also occurred on Eglin's ranges. In late 1953, Eglin's ranges substituted for an overseas location (as first planned), with these tests using simulant agent (*Serratia Marcescens*) procured from the Army's Pine Bluff Arsenal in Arkansas. For Operation Godunk of 1954, the Armament Center at Eglin tested the effects of flight conditions on a biological agent, aspects of agent storage before flight, aircraft suitability, and comparisons of ground versus air agent transport. Before the close of the same year, Eglin personnel evaluated the hazard of agents leaking from munitions while being loaded onto aircraft. The Air Force ran more "bacteriological warfare" tests at Eglin in April 1955. As of this year, buildings for BW-CW existed at Eglin, both at Field 6 on its ranges and in the weapons storage area on the main base.[206]

By about 1963, Eglin had built a "Biological-Chemical Munitions Test Area" at the southern edge of its Range 52A (C-52A). Testing at the C-52A grid supported agent warfare during the Vietnam War. The BW-CW facility

> was used for testing aerial delivery hardware for chemical and biological weapons by use of simulants. A one square mile controlled grid system was instrumented with fixed sampler stations and a one hundred square mile area surrounding the grid was also available for portable sampling equipment when greater dispersion measurements of simulants were required. The facility included a laboratory which housed the assessment and grid control equipment. Phototheodolites, power, and communications were provided to obtain position data and control the test missions. An extremely accurate micrometeorological system on the test area measured and recorded climatic conditions.[207]

The R&D arm of Air Materiel Command, and its successors ARDC and AFSC, also supported the special weapons mission during the Cold War through atomic and nuclear munitions programs. Involvement of the command was intense and varied, and over time included direct units at not just Wright-Patterson, but also at Eglin, Kelly, Kirtland, Cambridge, Holloman, McClellan, Los Angeles, Patrick, and Hill. Immediately following World War II, remotely controlled B-17 drones operated by the 1st Experimental Guided Missiles Group at Eglin sampled atmospheric radioactivity during the June-July 1946 Crossroads detonation tests of atomic bombs on the Bikini Atoll in the Marshall Islands. Eglin's drone flights for atomic tests in the Pacific, and later at the Nevada Test Site, continued into the 1950s. For the 14 full-scale nuclear tests run in Nevada after 1951, the 4925th Test Group (Atomic) from Kirtland flew the aircraft for the airdrop detonations.[208] Simultaneously, the depot arm of Air Materiel Command also began working with the AFSWP and the Atomic Energy Commission (AEC) to operate the aviation depot squadrons overseeing the Air Force classified storage areas for atomic, and then thermonuclear weapons components (see Volume I, Part II). Air Force classified storage areas involved primary management at Wright-Patterson, as well as onsite responsibility at 10 of the 13 sites in the continental United States, including Manzano Base on Kirtland and Medina Base near Kelly. With the establishment of the Air Force Special Weapons Center in 1952, ARDC also increasingly situated the R&D for atomic and nuclear weapons, and for the study of nuclear weapons effects and the development of hardened construction, at Kirtland.

While Eglin and Kirtland participated in supportive roles for the command's nuclear weapons R&D, efforts at Cambridge and McClellan focused on atmospheric testing during and following nuclear explosions, in an increasingly sophisticated manner. Like Kirtland, these installations sustained their nuclear role for many subsequent decades. The Cambridge Research Center conducted atmospheric

sound-channel studies using balloons launched from Holloman, Lowry, and Carswell (in Fort Worth) Air Force Bases for the second and third Greenhouse atomic-bomb detonations of April-May 1951 on the Kwajalein Atoll in the Pacific. Choice of these locations is presumably due to a low presence of subsonic background noise. At this date, Cambridge balloon studies were already several years old, but just gearing up for Projects Gopher and Moby Dick. Intent was to get "the over-all picture on the scientific model of the upper atmosphere."[209] As of 1951 the Cambridge Research Center, through its Atomic Warfare Directorate, also built up multiple capabilities related to atmospheric testing and evaluation. At Cambridge, ARDC established a Radiochemistry Laboratory to conduct R&D for "long range detection of atomic explosions;" a Radiobiology Laboratory under the Directorate to "investigate biological effects of radiation, particularly with reference to hazards arising in connection with delivery of the bomb;" and, a Physical Instrumentation Laboratory, in part to analyze "electromagnetic signals from atomic explosions."[210]

At McClellan Air Force Base in Sacramento, California—a maintenance depot for Air Materiel Command—the 374th and 55th Weather Reconnaissance Squadrons (WRSs), tied to AFOAT, flew constant missions to monitor the air for traces of radioactivity from possible foreign nuclear test detonations. The 374th and 55th WRSs brought back filter papers and sampler canisters for analysis (Plate 53). The interim WRS, the 374th, served at McClellan from late October 1949 into late February 1951. The permanent 55th WRS, partially collocated on base with the air defense mission of the 552nd Airborne Early Warning and Control (AEW&C) Wing, followed immediately and operated throughout the Cold War.[211] Both squadrons had derived from the recommendations of the Long Range Detection Committee of mid-1947. Representatives of the Secretaries of War and the Navy, as well as of the AEC and the Joint Research and Development Board, staffed the Committee. Its goal was to determine "the time and place of all large explosions which occur anywhere on earth, and to establish beyond all doubt whether any of them are atomic in nature." The Committee articulated future methodologies as including sonic, subsonic, and seismographic monitoring (such as the efforts of the Cambridge Research Center); aerial sampling "as near the scene of the explosion as practical;" and, chemical and radiological analysis of the gathered samples to further detail the type and nature of the detonation.[212]

General Curtis LeMay, Deputy Chief of Air Staff for Research and Development in 1947, commented that of the Committee's suggested methodologies for detection, only that of aerial sampling offered the possibility of detailed information. LeMay noted that it would be meteorologists who could analyze that kind of data, and that gathering it would be most likely within the domain of the AWS. He further suggested that the AWS be given the sampling assignment, commenting that the AWS already operated B-29 weather reconnaissance flights over selected aerial routes. By mid-November1947, the Air Force placed the fledgling long range detection mission under the Special Weapons Group, Deputy Chief of Staff, Materiel. As of early 1948, the Air Force reorganized the mission within Air Force Materiel Special Weapons-One (AFMSW-1), and physically located it at Gravelly Point, near Washington, D.C. In mid-year, the Deputy Chief of Staff, Operations, took over the long range detection assignment, with the Special Weapons Group renamed AFOAT. The Air Force subsumed the detection mission under AFOAT-1 through mid-1959. In late 1959, the administrative umbrella for the long range detection mission continued as the Air Force Technical Applications Center (AFTAC). The Air Force first headquartered AFTAC in Alexandria, Virginia; then at Bolling Air Force Base in Washington, D.C.; and, finally at Patrick Air Force Base in Florida. For a brief period during 1976 to 1980, the Air Force subsumed AFTAC under AFSC.[213]

The system into which McClellan's sequential WRSs fit, began through adaptation of an interim weather-service group in mid-1948. At that time 24 AWS aerial filtering units, which were designated as Reconnaissance Squadrons and later WRSs, combined with 22 northern hemisphere ground stations and took on the initial task of long range detection of atomic detonations. The AWS

Plate 53: 55th Weather Reconnaissance Squadron. Removal of a sampler canister at McClellan Air Force Base. Undated photograph. Courtesy of the History Office, McClellan Air Force Base.

ad hoc system followed immediately upon the completion of atomic tests during Operation Sandstone in the Pacific.[214] In September 1949, the 375th WRS picked up contamination in its paper air filters aboard its AWS RB-29 while flying one of its round-trip routes between Eielson (Alaska) and Yokota (Japan) Air Bases. The Soviet test detonation, Joe-1, was the first such foreign detection. Contractor laboratory analysis in Berkeley, California, augmented through additional WRS flights and recordings at AFOAT-1 ground stations, confirmed the event.[215] The Air Force activated the 374th WRS at McClellan immediately following Joe-1, and by the arrival of the 55th WRS in 1951, AFOAT-1 had also established its Western Field Office on base. The Western Field Office supported the radiological and chemical analysis of the contaminated air filters and sampled air from the flights of the WRSs. The laboratories of the Western Field Office (later, Technical Operations Division), like the 55th WRS, functioned in a high-level mission throughout the Cold War.[216]

As of the early 1960s, other ARDC / AFSC installations participating in the nuclear weapons mission were those of Los Angeles, Patrick, and Hill. Los Angeles Air Force Station (as of 1989, Base) sustained the efforts of the Western Development Division (WDD) and its follow-ons from 1954 forward, and had primary involvement in the R&D for multiple ICBMs. Los Angeles tested the missiles throughout the remainder of the Cold War using both static launch pads and live test launches over the Atlantic and Pacific ranges at Patrick Air Force Base in Florida and at Vandenberg Air Force Base in Southern California. The program also required specialized operations for testing aging missiles. The key example of this type of facility existed at Hill Air Force Base in Utah. At Hill, Air Force Logistics Command (AFLC) had the responsibility for the operation and maintenance of 14 igloos and seven silos for missile-aging tests of the Minuteman by 1964. The test program was to run a decade, with the objective of duplicating the temperature and humidity of the actual Minuteman silos.[217] Further aging tests continued for the successive generations of Minuteman and for the MX (missile experiment)-Peacekeeper.

Multiple other types of involvement with nuclear weapons existed across the commands of ARDC / AFSC and Air Materiel Command / AFLC. Issues of protective clothing, shielded buildings, informative programs, and even the handling of human remains following a nuclear attack all fell to differing components of the R&D and stored-materiel missions, with a number subsumed under the aeromedical mission. During the second half of 1952, for example, Air Materiel Command had undertaken a study to

> develop standard procedures for the recovery, preparation, and disposition of remains of deceased Air Force personnel who had been exposed in varying degrees to atomic radiation or biological agents. Close co-ordination was established with the Armed Forces Institute of Pathology, the Atomic Energy Commission, and other agencies engaged in related studies.[218]

Early special studies also fell to Air Materiel Command at Wright-Patterson, including ones to manage the design and engineering for the first Cold War command and control buildings for ADC in the late 1940s. The Air Force equipped these structures, remarkable for a variety of reasons, with filtering and decontamination systems designed to protect against the atomic-biological-chemical special weapons triumvirate. (See the Sophisticated Civil Engineering section below, and Volume I, Part IV.)

Sophisticated Civil Engineering

A highly sophisticated civil engineering mission existed within Air Materiel Command at the outset of the Air Force in mid-1947—a mission both with antecedents back through World War II and

forward through ARDC and AFSC during the Cold War. As of mid-1941, the Army's Chemical Warfare Service had initiated a state-the-art research program for incendiary bombs and had closely coordinated with the RAF in a parallel endeavor in Britain. Under the umbrella of the NDRC, the complex program had quickly included research laboratories at Columbia University in New York, as well as scientists at Brown, Chicago, Harvard, and Stanford Universities. Effective incendiary bombs had demanded accurate residential and industrial test structures, of both German and Japanese type. The key was an explicit verification of test-structure design and engineering. Two groups of expatriated German and German-trained architects in the United States and Britain made this possible. The American group included individuals residing in the Harvard-New York-Princeton triangle and in the Chicago-Detroit corridor. Eric Mendelsohn and Konrad Wachsmann participated in the program for German test structures, while Antonin Raymond provided parallel expertise for the design and construction of Japanese test structures. The NDRC oversaw the erection of authentic, large-scale infrastructure at the Army's Dugway and Aberdeen Proving Grounds in Utah and Maryland, respectively, and on the ranges at Eglin Field during 1943 and 1944. Related test structures also went up at the Huntsville Arsenal in Alabama (see Plate 39). Among the more astonishing aspects of this concentrated effort—with a counterpart of similarly designed German and Japanese test structures in England and Scotland—was Mendelsohn's submittal of actual photographs of modern German industrial architecture for analysis by the NDRC, including ones of his own masterworks.[219] When discontinued after the conclusion of World War II, the highest priority projects of the NDRC (and the connections derived from them) transferred to Air Materiel Command at Wright Field. The incendiary-bomb test program had been one of these projects.

As of 1946, events coincided to continue the wartime exposure to outstanding civil engineering. The Army Air Forces strengthened the Air Installations function within Air Materiel Command that year, simultaneous with the transfer of uncompleted projects from the NDRC. Recognizing the near-term independence of an air force, the Army Air Forces stipulated that Air Installations, Air Materiel Command, would take on an expanded role parallel to that of the United States Engineer (Army Corps of Engineers). When formalized in mid-1947, the Air Force would thus control and carry out the planning and execution for the many anticipated buildings and structures needed to augment its bases. In mid-1948, a joint Army-Air Force memorandum alluded back to the formative period for Air Force design.

> *For some time past* [italics added], the Department of the Air Force has been largely responsible for the actual determination of its construction. The Department of the Army has provided, and by joint plans will continue to provide, contractual construction services to the Department of the Air Force.[220]

Air Materiel Command had to decide how to handle its early Cold War civil engineering tasks: who would be responsible for what? Not surprisingly, the command appears to have concluded that the best route to success was to continue contractual relationships with key engineers and architects of pre-1946. In addition, the Air Installations Division within Air Materiel Command staffed up, with the further creation of a special studies office for orchestrating civil engineering R&D contracts by 1950.

By late June 1948, Headquarters Air Force correspondence among its directorates suggests a continued struggle between the existing Army Corps of Engineers and the parallel function operating within the Air Installations Division of Air Materiel Command at Wright-Patterson.[221] Close study of several important Air Force programmatic building needs of the 1947-1949 period also suggests that the Air Installations Division filled the "Corps of Engineers" role for two other Air Force commands, SAC and ADC. The continuation of complex NDRC projects, in addition to the surge of information

and talent provided by Project Paperclip, further stimulated the command's emerging civil engineering program. The pre-1950 convergence of these circumstances was often through the German engineering and architectural community: preexisting ties to German and Austrian engineers, sought-after German engineers via Paperclip, and the study of German architecture and engineering through direct observation. As of September 1951, Air Materiel Command still maintained a Corps of Engineers role for the Air Force through its Air Installations Division at Wright-Patterson, but began to delegate small engineering design responsibilities directly to the other commands (contracts under $25,000).[222] While the Air Installations Division appears to have worked out complex specifications and sustained an active role in civil engineering R&D, the division also relied heavily on contracting to private-sector engineers. A group of such engineers was solidly in place by mid-1953.[223] The overall situation for the Air Force continued to be unusual well into 1954, with the responsibility for construction engineering contracts acknowledged as split between "the Corps of Engineers, U.S. Army; Bureau of Yards and Docks, Department of the Navy; and the Air Materiel Command."[224] The following examples illuminate the struggle.

An Underground Pilot Plant for Air Materiel Command

The first major example of the phenomenon of sophisticated civil engineering within Air Materiel Command arrived with the competition between the Air Force and the Army for an underground pilot manufacturing plant. Efforts began with continued attempts to analyze the engineering details of German heavy, reinforced concrete construction, and were specifically focused on certain types of facilities employed by the Nazis during the war. While Army Air Forces and NDRC projects of 1944-1945 had opened this topic for scrutiny, with test infrastructure at both Aberdeen in Maryland and Eglin in Florida, the ending of the war had aborted the earliest attempts at understanding German bombproof construction.[225] After VE (Victory in Europe) Day in June 1945, the Americans and British jointly accelerated attempts to destroy and to replicate German reinforced concrete construction. Progress in the endeavor occurred through actual bombing of German industrial structures, beginning with a V-1 launch complex. During 1946 and 1947, the Army Air Forces and the RAF undertook Projects Ruby (flown with Eglin personnel) and Harken, which were bombing missions against German submarine pens and manufacturing sites. Simultaneously, the Army Air Forces, through the Joint Intelligence Objectives Agency (JIOA), collected detailed written and visual information on the German engineering of such buildings. As of September 1945, JIOA reports included *German Submarine Pens in France*, *Messerschmitt Bombproof Assembly Plant*, and *German Underground Installations*, among others. By February 1946, the Army-Navy Munitions Board (ANMB) established an Underground Sites Committee to explore ideas for underground munitions storage and manufacturing.[226] The Industrial Planning Section of the Logistics Planning Division, Plans (T-5) at Wright Field digested German World War II achievements, including German submarine pens, and wrote about them in a subsequent report of June: *A Recommended Program for the Underground Manufacture of Aircraft (Initial Phases)*. During the remainder of 1946, the Combined Intelligence Objectives Sub-Committee interviewed numbers of German engineers and military authorities, collected original construction photographs and site drawings, and drafted hundreds of reports. The only major American project of World War II that received scrutiny was an underground air depot in Hawaii. The Army had planned that installation in early 1941, constructing the facility during 1942-1943 but actually never using it.[227]

The intense study of German reinforced construction during mid-1945 through 1946 led to memoranda of early February 1947, in which Air Materiel Command concentrated on devising methods of obtaining as much explicit information as possible from the German engineers themselves. Discussions between Plans (T-5) and Intelligence (T-2) at Wright Field turned to using Project Paperclip for this purpose, with the intent to first extensively interview engineers held or available in Germany. Paperclip, by definition, did not encourage the importation of civil engineers,

but instead focused on expertise interpreted as directly military or industrial. Only late in Paperclip did attention turn to accessing civil engineers, and the use of the Paperclip vehicle to do so. As of May 1947, T-5 of Air Materiel Command asked six architectural-engineering firms to submit proposals for the underground project: Allen & Kelley of Indianapolis, Blaw Knox of Pittsburgh, Giffels & Vallet of Detroit, Hazelet & Erdal of Cincinnati, J. Gordon Turnbull of Cleveland, and Sverdrup & Parcel of St. Louis. Each of these firms had a preexisting, or contemporary, connection to Air Materiel Command or the Army. Giffels & Vallet was the firm responsible for the Army's standard protective-construction igloo of the early 1940s. Hazelet & Erdal was working on the all-wood radar test facility at Wright Field, similar to the wooden dirigible hangar designed and engineered by the Navy's Arsham Amirikian during the early 1940s. The firm had previously designed the static test laboratory at Wright Field that was able to accommodate the fuselage of the B-36. Sverdrup & Parcel was in the process of site studies for the plan and development of AEDC. J. Gordon Turnbull, however, won the contract. The prior military experience of Turnbull's firm was in master planning for several Materiel Command depot installations (such as at Tinker Air Force Base in Oklahoma) early in World War II, and for selected structures requiring heavy construction. Two of these latter commissions were the standard Army Air Forces Armament-Fire Control Supply and Repair Building, for work on Norden bombsights, and the Engine Test Building (see Volume II, Chapters 6, 11, 12, and 13).

Turnbull's firm developed a refined expertise in protective construction through the Air Materiel Command underground plant project. Firm members traveled to Germany to interview engineers first-hand. The command also forwarded German engineering reports and pertinent original drawings to the firm. Not surprisingly perhaps, J. Gordon Turnbull handled several very important commissions for the Air Force in the early 1950s following upon the precedent-setting work on the underground pilot plant project. Although the Air Force continued to hire Turnbull for master planning activities (such as at Eglin Air Force Base in 1950),[228] by 1951 J. Gordon Turnbull had contracts for the Basic Information Folders (BIFs) set up for the Topeka and Cheli (Maywood area, Los Angeles) special depots[229] (see Volume I, Part II). The firm's major work of 1951-1952 also included multiple contracts for construction of airfield facilities, buildings, utilities, and petroleum, oil and lubricant storage in Japan that totaled nearly $670,000 in professional services.[230] During the middle 1950s, J. Gordon Turnbull continued specialized engineering for ARDC needs through the design and engineering of launch structures for Bomarc.[231]

As of summer 1947 and into early 1948, Air Materiel Command's concentrated efforts toward this first major Cold War project requiring specialized civil engineering expertise intensified. The command's focus was protective infrastructure for the era ahead, which began with an understanding of the world's best bombproof construction—that of late-war Germany—and moved toward an ability to engineer structures capable of withstanding the aftermath of the emerging nuclear weapons. "Protective construction" would be an endeavor steadily pursued by ARDC and AFSC. It was a significant special mission almost invisible to the public and very much tied to the other special mission of the command—biological, chemical, and nuclear weapons development. In mid-July 1947, memoranda on the underground pilot plant project of Air Materiel Command included explicit references to the need to address "Chemical Warfare (CW), Biological Warfare (BW), and Radiological Warfare (RW)."[232] The Germans had developed major underground sites during the war, ones that had typically taken advantage of existing mines, man-made tunnels, and caverns. The underground pilot plant project of Air Materiel Command would also incorporate natural landscape features.[233] As of August, Wright Field became the

> focal point for the collection of all foreign information on underground plant programs...authorized to assume the responsibilities for the translation and reproduction of this

> information for the AAF and for its dissemination to elements of the AAF and to other interested agencies. Close coordination will be established with the Navy, Bureau of Mines and Corps of Engineers.[234]

The underground pilot plant project reached across Air Materiel Command, absorbing personnel in T-2, T-3, T-4, and T-5. Intelligence (T-2) handled data analysis and technical translations, with Paperclipper Georg Rickhey assigned to the Analysis Division of T-2 in "the position to act as a technical consultant on AMC plans for underground factories." Rickhey had arrived at Wright Field by April 1947, and had been the general manager of Mittelwerke, the V-2 production plant in Nordhausen. He was in charge of that plant's underground facilities during the war. Mittelwerke covered 2,750,000 square feet in its below ground operations, and at the end of World War II had an additional 5,000,000 square feet of underground construction underway. The underground manufacturing of V-2s at Nordhausen had used two parallel railway tunnels as its core facility, with each over a mile in length through the Kohnstein Mountain. Mittelwerke had relied on concentration camp labor. Many of its inmates were dead, or dying from overwork on the V-2 assembly-lines, when the Allies captured the facility in 1944. The manufacturing site had also yielded the components of 100 V-2s for shipment to the United States, to accommodate testing established thereafter at the White Sands Proving Ground in New Mexico. Other German scientists at Wright Field assisted in the technical translations for T-2. Rickhey was a notorious war criminal. Of note, the mid-May 1947 list of Paperclippers at Wright Field does not include Rickhey. Nor does the list of the Paperclippers present anywhere in the United States, or on future order, include Rickhey in mid-June 1947—although he is called out by name as a key participant in the underground plant project, and as physically at Wright Field, only months earlier. The assumption is that Rickhey was among the too-hot-to-handle Paperclippers, sent to Rome Field (the later Griffiss Air Force Base) before return to Germany by early 1948.[235] The Air Materiel Command underground pilot plant, as of early August 1947, was explicitly intended for the manufacture of jet engines.[236]

In September 1947, an Air Materiel Command team of seven personnel, including J. Gordon Turnbull and members of his firm,[237] traveled to Germany to interview about 40 German engineers over a six-week period. The team also visited 18 underground military industrial sites in Germany, Sweden, and France. Among the interviewed engineers was Franz Dischinger, the key developer of the Z-D (Zeiss-Dywidag) construction technology for Dykerhoff & Widmann during the late 1920s, and a professional colleague of Anton Tedesko's both before and after the war. Dischinger worked as a consultant to *Organization Todt* during World War II—the Third Reich equivalent of the Army Corps of Engineers. *Organization Todt*, named for the civil engineer Fritz Todt, engineered and built many of Germany's military airfields and fortifications. In classified Army correspondence of early 1948, Air Materiel Command sought to bring four of Germany's leading military civil engineers to the United States under Paperclip for expertise in underground and protective construction. These men were Xaver Dorsch, Walther Schieber, Woldemar Gerhardt, and Dischinger. Dorsch, an engineer who had worked directly under Dr. Todt during the late 1920s and early 1930s, had supervised the building of the German railways as well as the Autobahn around Berlin, Stettin, Hamburg, Hanover, and Kassel. As of 1941, Mr. Dorsch headed *Organization Todt*, and as of May 1944, managed the *Amt Bau* (Structures Division) of the civil engineering bureau—specifically "for all of the building under Secretary Speer, especially for the planning and construction of underground factories in Germany and the occupied territories."[238] Mr. Gerhardt had majored in mining engineering, and had been in charge of the metal industry during the war. In 1938, Gerhardt had been an exchange scholar in the United States.[239] Mr. Schieber was a chemist, responsible for building viscose factories in Germany, France, Belgium, Russia, and Poland between 1935-1944 (a number underground), and distribution chief for the factories under Speer after 1942.[240]

Of the four men sought by Air Materiel Command—Dorsch, Schieber, Gerhardt, and Dischinger—only Gerhardt was considered "immediately available" as of mid-February 1948. The command had tried to procure German engineers for the underground plant as early as June 1947 under Project Paperclip. United States Air Forces in Europe (USAFE) had recommended Dorsch and Schieber, but had suggested Oskar Gabel and Helmut Ewald instead of Gerhardt and Dischinger. Gabel had been the Chief Inspector of Mines in Nazi Berlin, and had supervised all dispersed underground factories in the mines during the war. His professional stature was parallel to that of Dischinger.[241] Air Materiel Command's records listed Ewald as a Munich engineer of lesser standing than Dischinger, but in a select planning group of three considered for the project.[242] Each of the men considered wrote specific reports for the command tied to their areas of expertise: Dorsch (administration), Dischinger and Ewald (planning), Gabel (mines), Gerhardt (iron and steel), and Schieber (chemistry).[243] In early 1948, neither Dorsch nor Schieber had appeared before the denazification court and the outcome of their trials was undetermined. Men awaiting trial were held in confinement. The situation made them useable by the Army for underground installations analysis, with the high likelihood of their cooperation due to the issue of the slave labor employed in the underground facilities. Once the denazification trials had taken place, men were either sentenced and imprisoned, or could return to civilian positions in Germany. Generally, civil engineers did not wish to leave Germany unless pursued by the probability of criminal sentencing.[244] The Army (also working toward the acquisition of civil engineers) considered Dorsch, although highly important, as primarily supervisory in skill, and concentrated on Dischinger. Interpretation of Dischinger's actions, motives, and desires was, and remains, mixed. The Army noted in a classified message of 18 February 1948:

> Dischinger is frequently approached by the Soviets and is believed to be doing some work for them. It is believed he will sign a British contract however if the United States does not immediately agree to the inclusion of his assistant in the United States offer accorded him.[245]

Dischinger continued to be highly cooperative into 1948, but did not agree to come to the United States. At the request of Air Materiel Command, Dischinger prepared designs for a protective bunker intended to withstand a 20,000-pound bomb—a document submitted along with the reconnaissance reports of the existing World War II underground installations. The situation was similar to the Army-supported aeromedical research undertaken by Dr. Strughold and his team of German doctors in Heidelberg during 1945-1946. Dischinger's "blue printing of futuristic underground constructions...[fell]...under the classification of research and...[was]...illegal in Germany."[246] Unexplored, to date, are Dischinger's actual ties to the United States as of 1946. German biographies record this period minimally, but note that he taught in the newly founded Technical University in Berlin between 1946 and 1951, very possibly in a sustained research link to the United States akin to the American subsidy of the School of Aviation Medicine in Heidelberg. In 1950, Dischinger and Tedesko verified the test specifications for a futuristic ribless, Z-D concrete shell through correspondence. During this effort Dischinger was in Berlin, Tedesko in Chicago. The technology would be used in a very large warehouse for Air Materiel Command at the Olmsted Air Force Base depot near Harrisburg, Pennsylvania, in 1957 (see Volume I, Part II). One of the older German professionals considered for Paperclip, Dischinger was 60 years of age at the time of his work on underground installation designs for Air Materiel Command in 1947. The highly talented engineer died in Berlin in 1953.[247]

While the R&D process went forward for the Air Materiel Command plant, the Army Corps of Engineers also commissioned a study for underground facilities. In May 1947, the Corps hired the New York firm of Guy B. Panero to develop planning information for two types of pilot plants: a

chemical processing plant and a precision machine manufacturing plant.[248] The military authorities interpreted the three endeavors—a jet-engine plant (Turnbull), a chemical plant (Panero), and a precision machine plant (Panero)—as sufficiently distinct from one another to move ahead on parallel tracks with the two architect-engineers simultaneously. By late 1948, the Corps' project also included a pilot storage depot, with the selected sites in Tennessee (chemical), Illinois (precision machine), and Georgia (storage depot).[249] Nonetheless, strong differences existed in the methods used by Air Materiel Command and the Corps of Engineers in their competitive pursuit of German civil engineering expertise in protective underground construction applicable for the American military. Only the general contributions of Paperclipper Rickhey (and possible continued long-distant exchange with Dischinger) appears to have complemented Air Materiel Command's comprehensive interviewing, document gathering, translating, and creative use of engineers in Germany. The Corps also sent Panero to Germany, but relied on Air Materiel Command's gathered materials for the study of the problem. The Corps also wanted four civil engineers to come to the United States as Paperclippers, hiring at least two men on short-term contracts. In early 1948, Dr. Franz Reidl arrived to work at the Corps' engineering center at Fort Belvoir, Virginia, to assist Panero in the Corps' underground project. Dr. Reidl's background was in the heavy, reinforced concrete construction of the submarine assembly plant at Farge. He prepared a detailed description of the facility for the Corps. Dr. Karl Fiebinger followed in June, simultaneous with Reidl's repatriation to Germany. Dr. Fiebinger's expertise focused on underground oil refineries for Nazi Germany. These highly specific Paperclip contracts ran only a few months, although Dr. Fiebinger remained in the United States through a release agreement to the American-Austrian Export Import Corporation in New York.[250]

The work toward the Air Materiel Command underground plant continued into 1949, before termination of both the Turnbull and Corps projects. By late July 1948, the command had selected a large limestone mine in Greer, West Virginia, as the site for its plant. The location in the northeastern part of the state featured "adequate over-burden" with "rooms of suitable width and ceiling height." The Air Force could camouflage the site easily and felt it to be well-situated with respect to jet-engine suppliers. Size for the $10,000,000 plant was to be 428,000 square feet.[251] Engineers designed the plant to withstand the impact of a "42,000 pound bomb." Overburden of limestone, sandstone, and shale at the Greer site was 200 to 500 feet, which was more than twice that present at the other nine final sites in consideration by the command. The rooms were 60 feet wide and 35 high, with a configuration flexible enough to accommodate a variety of manufacturing pertinent to the aircraft industry.[252] The Air Materiel Command underground plant was also designed to operate during a biological or chemical war. Detailed analyses noted that biological and chemical warfare agents would tend to settle in low places after remaining wind-born for a period. An ideal entrance to an underground military facility was felt to be on the leeward side of a hill. Such was the case at Greer, with mine entrances 100 feet above the valley floor and leeward to the prevailing winds. Turnbull's firm made provisions for decontamination. The firm planned a garage to house tank trucks that would be used to mix and spread chloride of lime slurry after a weapons episode. For the interior of the plant, J. Gordon Turnbull devised additional mechanisms to shield the facility against both biological and chemical warfare agents, including "pressurizing, air conditioning, filtering, and controlling the air [through] the air conditioning system."[253] As of September 1948, however, the Air Force was moving away from building the underground project, which by this date was known alternately as the "Uncle Slant George Project."[254]

Although the government fully abandoned the Air Materiel Command and Army Corps of Engineers underground plants after the Soviet detonation of an atomic device in late August 1949, other major underground project plans persisted during the 1946-1955 period. One of these was the foreshortened, inclined runway. The Army Air Forces had constructed a 10-percent inclined runway, about 2,300 feet long, at Wright Field in 1942. Materiel Command (and the follow-on Air Technical

Service Command) had used the facility to test several aircraft during the next few years, including the B-17, B-18, and B-29. Intriguingly, photographs also illustrate a B-50 (a modified B-29) positioned on the runway in 1953, although little is known about use of the airstrip during this later period (see Plate 8).[255] Alternately termed a "downgrade runway," the inclined airstrip was a feature of underground hangars—a concept of interest to Air Materiel Command and ARDC during the early years of the Cold War. In March 1955, the Air Force specifically discussed a proposed coupling of underground aircraft facilities and inclined runways for a natural rock site in California, referencing both the downgrade test runway at the WADC and "[existing] [u]nderground construction...for various [military] facilities." Advantages of the idea were "concealment and physical protection," while disadvantages included "relatively high costs."[256] It is possible that Korean War tests using the downgrade runway at Wright-Patterson in the early 1950s related to further experimentation toward underground hangars. In October 1950, United Nations forces occupied Wonson Airfield in North Korea and discovered two underground hangars at that location. By 1952, the Joint Air Defense Board at Ent Air Force Base near Denver sponsored two studies on aboveground and underground protected aircraft shelters—with the Directorate of Air Installations, Headquarters, involved as of the next year, possibly with a subordinate role through Air Installations, Air Materiel Command.[257]

Early Cold War Air Force interest in underground installations peaked during 1948 to 1952, with increasingly sophisticated construction—including hardening—in the decades thereafter. While Air Materiel Command planning for the underground pilot plant went forward, the Army Corps of Engineers, Bureau of Reclamation, and the Civil Engineering Department of Yale sent seven men to the second international congress on underground town planning and construction, held in Rotterdam, the Netherlands, during 10 days in June 1948. A Corps of Engineers attaché to the American Embassy in London compiled a lengthy report on the proceedings for the Air Force.[258] Late in the same year, both the Directorate of Air Installations, Headquarters Air Force, and the Army Corps of Engineers, reviewed a "surface-subterranean" building proposed by the Toledo Testing Laboratory as yet another solution to protective construction.[259] The combination of aboveground and underground units, in a single structure, would be the solution pursued by the Air Force as of the middle 1950s. Yet another example was SAC's December 1952 proposal for locating some of its Snark guided missile launch facilities in underground installations, as well as future Navaho and Atlas facilities. By the early 1960s, of course, SAC would launch ICBMs like Atlas, Titan, and Minuteman from underground silos. In 1952, considerations for underground missile launch sites still focused on "the possible use of existing mines, caves, excavations, etc."[260]

One example of an underground facility from the early 1950s engineered within an existing cave is that of Project Greek Island in southeastern West Virginia near White Sulpher Springs. Built during the administration of President Dwight Eisenhower, Project Greek Island was 720 feet underground. Greek Island served as a bunker for emergency occupation by members of the Senate and House of Representatives in the event of nuclear attack. The West Virginia underground installation directly continued the late 1940s work of Air Materiel Command and the Army Corps of Engineers. Construction crews completed Greek Island in the early 1960s. The installation at White Sulpher Springs was very similar to the plans for the Greer site in the northern part of the state. It featured an entrance shielded by a heavy concrete-and-steel blast door; a long concrete tunnel; and, a decontamination chamber with shower heads, where entrants would remove contaminated clothing for destruction. The next known sophisticated civil engineering project undertaken by Air Materiel Command—also protective, but aboveground—featured several of these same unusual parameters. Like the Air Materiel Command plant, the Congressional bunker was also to have living quarters and amenities for a sustained period, in this instance including convening chambers for the Senate and House, communications rooms, dormitories, a medical clinic, a kitchen, and a cafeteria.[261]

Control and Direction Centers for Air Defense Command

After World War II, the Army Air Forces quickly turned to issues of homeland air defense that were emerging with the onset of the Cold War. Nascent radars and fighter control centers had gone in place in the middle 1940s, with the very limited control centers modeled directly after ones in Britain. Establishment of an integrated network of radar, command and control, and squadrons of alert fighter aircraft, however, was an effort of the 1950s. ADC computerized the mature air defense system at the end of the decade through SAGE and its follow-ons. By 1949, both the Cambridge Research Laboratories in Boston and the Rome laboratories (subsequently, the RADC) at Griffiss Air Force Base in New York initiated major roles in developing the electronics required for an air defense system (see Volume I, Part IV). The role of Rome centered on its Data Utilization Laboratory, transferred from Cambridge to the Griffiss location in 1948, with both Cambridge and Rome deriving their air defense mission from that continuing at the Watson Laboratories in New Jersey. Cambridge formally sustained an Air Defense Office after meetings of the Valley (Dr. George E. Valley, MIT) Committee organized through the SAB in December 1949.[262] Cambridge worked concertedly on the SAGE program after its laboratories moved to Hanscom Air Force Base. There, the Cambridge Research Laboratories (Center) supported an Experimental SAGE building erected immediately adjacent to the MIT Lincoln Laboratory, an air defense laboratory complex. By late 1952, Cambridge also operated an Experimental Air Defense Direction Center (ADDC) at North Truro on Cape Cod. From the beginning, the focus of Cambridge was on the functional linkage of automated communications equipment between command centers, radar stations, and fighter aircraft. Cambridge's work also concentrated efforts toward systems that would contribute to SAGE (initially named the Lincoln Transmission System).[263] At Hanscom, even the assigned fighter-interceptor squadron (FIS), complete with standard alert infrastructure, partially served as test support for the electronics of SAGE.[264] During this early period in the development of an air defense network, the RADC addressed the display and analysis of the gathered data. Personnel at the RADC improved the designs of the vertical and horizontal plotting boards present in command-post war rooms.[265] Griffiss sustained an Experimental Operations Room for this purpose as of 1951-1952.[266] In 1949, the Watson Laboratories had run an earlier Test Operation Building at the General Electric facilities in Syracuse, New York, which served much the same function as the subsequent test facility at Griffiss.[267] By the early 1950s, the 32nd Air Division (Defense) had its control center at Syracuse Air Force Station. Late in the decade, ADC erected a combined SAGE Combat and Direction Center on site, one of three such paired complexes nationwide.

The existence of Fighter Control Centers as of 1943-1944 (Volume I, Part IV), and the full-blown entry of the Cambridge Research Laboratories and the Rome Laboratories into the planning for a comprehensive air defense system in the continental United States in 1949, leaves a gap of five years between a system of World War II and one emerging at the outset of the Cold War period. Within this gap, the Electronics Subdivision of the Engineering Division of Air Materiel Command, working at the Watson Laboratories, began to seriously address progress on the nation's air defense network as of 1946. Discussions all pointed to what would become the work of Cambridge and Rome, with studies typical of each already underway. As of mid-year, at a conference held at the Watson Laboratories, specific listed projects were numerous. These projects referenced improvements to the Fighter Control Center and plans for a new Air Defense Control Center (ADCC), *simultaneously*. The visionary air defense network of the middle 1940s forward aptly featured many complexities.

> The Air Defense System of the future is expected to evolve into a practically automatic system. Present technical limitations, however, require the employment of personnel for many functions not yet refined to the point where they can be performed unattended. The immediate Electronic Air Defense planning of the Army Air Forces

> provides for the improvement of short and medium range radio, radar, and navigation equipment and their integration into a system under the control of an Air Defense Central.
>
> Extended Air Defense planning provides for greater ranges of detection and control of defensive mechanisms under the direction of the Air Defense Central. The use of close cooperation techniques, navigational aids, and beam riding techniques for control of defensive missiles is to be linked through computing and flight predicting devices with an Air Defense Central which utilizes information obtained from improved radars providing high speed scanning, velocity discrimination and extended range. Radio and radar links, both ground and airborne, are required to provide rapid transmission of data to the Air Defense Central, to provide channels for control of electronic countermeasures and to direct defensive batteries of missiles and aircraft.[268]

Interim radars and the beginnings of an air defense network required an infrastructure. Between mid-1946 and late 1948, the task of developing specifications for design of the future ADCC and ADDC fell to Air Materiel Command—operating like the Corps of Engineers for the Air Force, and yet leaving the Corps a construction-management role. Air Materiel Command handled the front-end development of the technical parameters required for the command and control buildings. The command then contracted with a prominent architectural-engineering firm to execute the actual design. The process for developing the air defense command and control centers was an extremely fluid and complex one that was orchestrated by Air Materiel Command for Continental Air Command (CONAC)—the Air Force command created by combining ADC and Tactical Air Command (TAC) in 1948. Within CONAC, ADC remained in charge of the Cold War air defense mission. Again, the mission of providing civil engineering expertise within Air Materiel Command focused on protective construction. By 1948, if not before, Headquarters CONAC at Mitchel Air Force Base on Long Island, New York, had communicated to the Directorate of Installations, Headquarters Air Force, that the World War II Fighter Control Center (known as Building H) at Roslyn, New York, should serve as a starting point for design of the Cold War first-generation air defense command and control centers.[269] Designed by Skidmore, Owings & Merrill of New York in mid-1943, the Fighter Control Center was a partially below-ground structure. Thick reinforced concrete walls and ceiling protected its basement, although the first-story component of the Fighter Control Center was woodframe. A tall ventilation tower to the basement rose above the first story, with the assumption that toxic gas used in warfare would be heavier than the ambient air and would sink to ground level quickly. Gas-proof louvered vents in the tower, as well as gas-proof doors to the basement further protected the air defense control mission operating below ground. The woodframe upper structure was windowless.[270]

Air Materiel Command interpreted the ADCC and ADDC as partially bunkered structures: heavy reinforced concrete, column-and-beam construction with double concrete-block exterior walls. The walls were eight and four inches thick, respectively, and featured a two-inch air pocket. Records label the concrete block as "pumice block," possibly a form of early barite concrete, which was a high-density material used for biological shielding in about 1960.[271] Specific systems incorporated into the structures addressed Air Force concerns about radiation, as well as biological and chemical warfare. The ADCC and ADDC (Plates 54-58) were windowless and featured:

- double inner and outer air locks;
- decontamination chambers with showers;
- clean clothes storage;

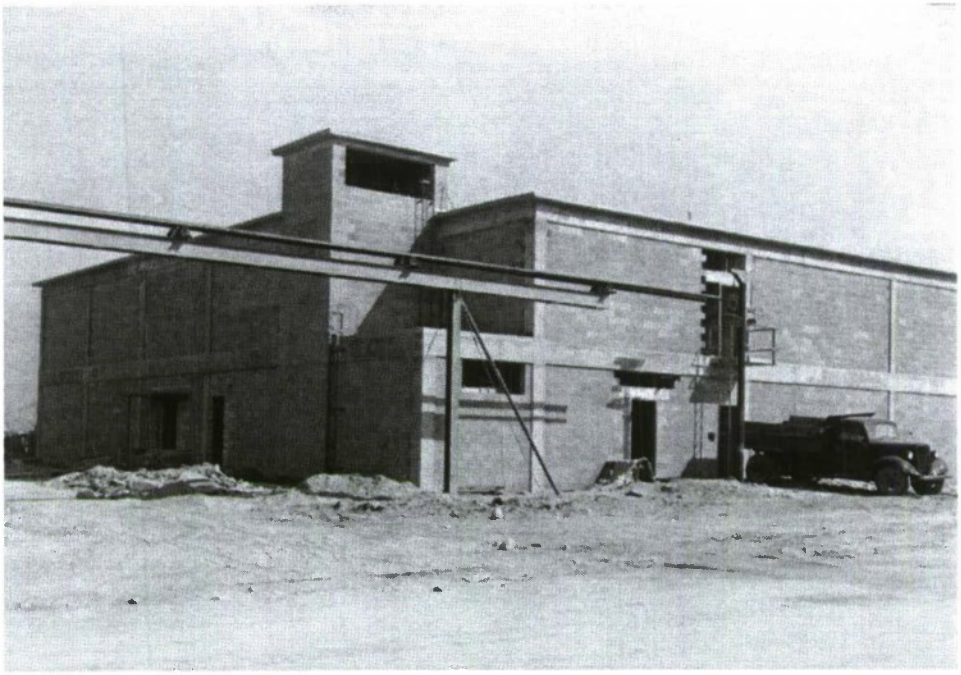

Plate 54: Holabird, Root & Burgee. Air Defense Control Center (ADCC) for the 27th Air Division (Defense), Norton Air Force Base, March 1951. In *History of the 27th Air Division (Defense) 1 January – 31 March 1951.*

Plate 55: Command Post (War Room) within the 27th Air Division (Defense) ADCC, Norton Air Force Base, 1951. In *History of the 27th Air Division (Defense) 1 January – 31 March 1951.*

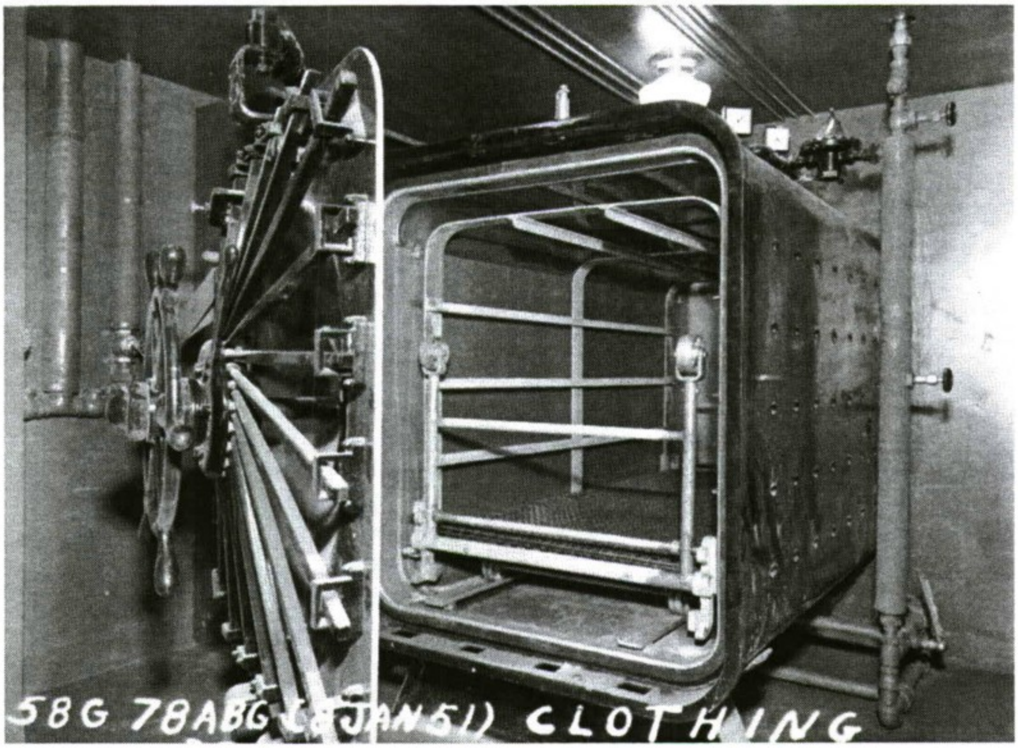

Plate 56: Clothing Decontamination Unit in the 27th Air Division (Defense) ADCC, Norton Air Force Base, 1951. In *History of the 27th Air Division (Defense) 1 January – 31 March 1951.*

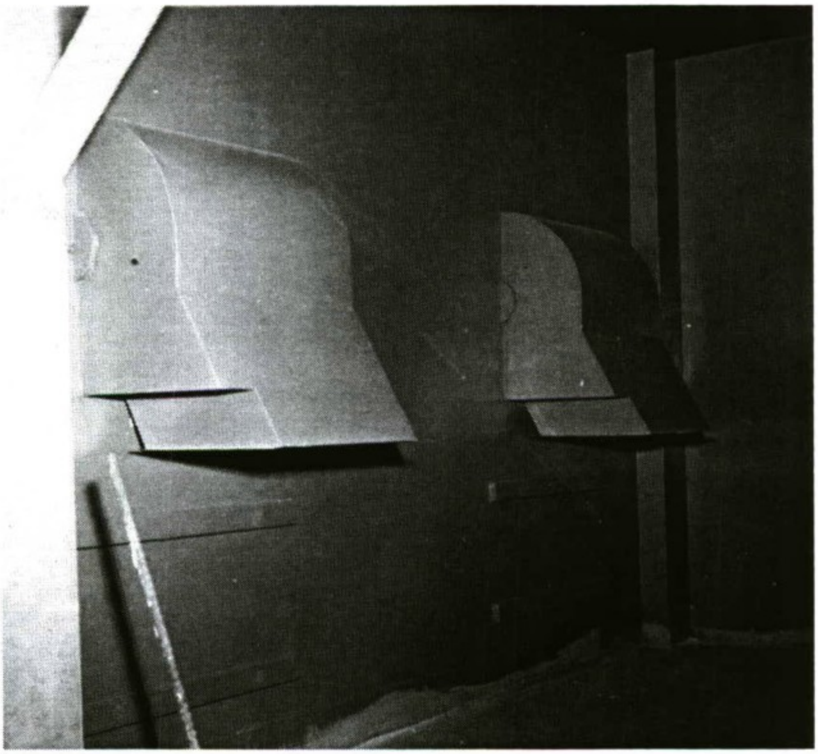

Plate 57: Gas-Proof Clothes Chutes in the 27th Air Division (Defense) ADCC, Norton Air Force Base, 1951. In *History of the 27th Air Division (Defense) 1 January – 31 March 1951.*

Plate 58: Decontamination Chamber (Showers) in the 27th Air Division (Defense) ADCC, Norton Air Force Base, 1951. In *History of the 27th Air Division (Defense) 1 January – 31 March 1951.*

- a contaminated clothes area with disinfector;
- gas-proof clothes chutes and doors;
- provisions for sustained pressurization (with two blower rooms for controlled air conditioning);
- filters for all outside air access; and,
- a ventilating shaft.

The intent was to maintain a slight positive pressurization inside the structures, forcing all air leaks outward and keeping air contaminated through biological or chemical agents outside the building. (The Navy called this process "slanting" during the early 1950s, terminology still used by SAC in 1960).[272] These features were all discussed by interviewed German engineers participating in the Air Materiel Command underground plant project of 1947-1948.

By October 1948, the Air Installations Division achieved the basic specifications toward the ADCC and ADDC: "it is understood that the Air Materiel Command has spent considerable time developing plans for technical buildings."[273] The Deputy Chief of Staff, Operations, at Headquarters Air Force, instructed the commander of ADC, subsumed within CONAC and also with headquarters at Mitchel, to consult the specifications of Air Materiel Command. These specifications included the anticipated air defense buildings by square footage and the required parameters for the ADCC, the ADDC, the radio station building, and the associated power station. The scope labeled the "technical buildings" planned by Air Materiel Command as "operations buildings," with specific variations for four types of structures: the ADCC, the Air Direction Center – Heavy (ADC-H), the Air Direction Center – Light (ADC-L), and the Early Warning Station (EWS).[274] The operations, radio, and power buildings

called for varying degrees of gas-proofing, decontamination, air conditioning, omission of all windows, and noncombustible construction. The Corps of Engineers was responsible for managing the initial $175,000 engineering contract for Air Materiel Command, including all of the basic support (nontechnical) buildings at the ADCC and ADDC sites (barracks, mess hall, recreation building, storehouse, dispensary, and associated structures—closely following existing standardized Army design). Known in 1948-1949 as Project Fence, the air defense network would operate as Aircraft Control & Warning (AC&W) installations. As of 26 January 1949, Air Materiel Command assigned the architectural-engineering contract for the ADCC and ADDC program to the Chicago firm of Holabird, Root & Burgee. [275] During World War II, the firm had designed a group of experimental all-steel, concrete-block, and hollow-tile barracks at Camp Grant, Illinois, and was also responsible for pioneering work for Illinois Bell Telephone.[276]

Design meetings were underway by mid-February 1949, with the Corps requesting continued specifics from the Directorate of Installations into late March: width, length, and height of structures; cable trench sizes, lengths, and placements; functional layouts with sizes of all designated rooms; as well as other "essential requirements."[277] By the outset of May, the Directorate of Installations at Headquarters Air Force further decided to remove all references to the air defense mission from the title blocks for the command and control buildings. The Directorate of Installations imposed a security classification on the drawings themselves. At this point, the EWS became the "Type 1 Station;" the ADC – L, the "Type 2 Station;" the ADC – H, the "Type 3 Station;" and, the ADCC, the "Type 4 Station."[278] Nomenclature would evolve further in the early 1950s. As built, the ADCC was a Type 4 Station and the ADDC, a Type 2 Station. The Type 1 Station functioned at AC&W radar installations similarly to the Type 2 Station, but was not designated as an ADDC. The Type 3 Station became an administrative unit attached to the ADCC (the Type 4 Station).

The design and engineering process for the ADC first-generation command and control buildings also illustrates the larger Air Force civil engineering mission during the late 1940s and early 1950s. Using the scope developed by Air Materiel Command and the refinements developed by the Directorate of Installations, Headquarters Air Force, Holabird, Root & Burgee produced preliminary drawings for the project in early April 1949. The Corps of Engineers next held a meeting at Mitchel Air Force Base with representatives of CONAC to discuss the designs. Following the meeting, the Corps transmitted the designs to the Directorate of Installations at Headquarters Air Force. The Corps attached recommendations for design changes. As of mid-June, the Directorate of Installations at Headquarters Air Force suggested specific revisions of multiple types to CONAC. One example was a call for moving the decontamination unit featured in each of the operations buildings to the end of the structures, rather than at the sides where it was originally designed. The Directorate of Installations interpreted the original location of the decontamination chamber as interfering with the below-ground cable duct entrances. CONAC concurred with this assessment.[279] By mid-July, the Directorate of Installations met with the Corps in Washington to discuss needed revisions to the plans "for efficient handling of atomic, radiological, biological and chemical personnel decontamination." Comments of the Headquarters Air Force civil engineering office focused on the number of decontamination showers in the operations buildings, the possibility of "radio-active emanations from material being concentrated in these [shower] traps; the need for "vapor seals for chemically contaminated clothing in order to prevent hazardous vapor concentrations," "nonporous easily decontaminated surfaces," "[n]o windows," and an exit door on the opposite side of the building from the outer lock at the decontamination area; and, the arrangement of the dressing rooms.[280] At about this same time, the Directorate of Installations instructed the Corps to have Holabird, Root & Burgee focus on air conditioning for the full interiors of the operations buildings, on gasproof construction, on air locks, and on careful consideration of the locations of entrances, exits, vents, and louvers. Holabird, Root & Burgee suggested the use of a "cavity wall type of construction" in lieu of a solid 16-inch masonry wall, to achieve a "desired thermal conductivity."

The Corps concurred with the architectural-engineering firm's feature and recommended it back to the Directorate of Installations.[281]

Such interaction between the Directorate of Installations, Headquarters Air Force, the Army Corps of Engineers, and CONAC, additionally received further contributions from Air Materiel Command. In one instance, the 3151st Electronics Station at the Watson Laboratories in New Jersey recommended wall and ceiling colors, lighting, and soundproofing measures to best accommodate effective command and control. For the operations buildings, the Watson Laboratories suggested schemes derived from its Test Operation Building at General Electric in Syracuse: pastel green with dark green trim for most rooms and a very dark blue for the operations and indicator rooms, with white ceilings. Personnel of the Watson Laboratories argued that attention to this kind of detail helped to insure human accuracy, complementing the ever-improving technology of radar and communications equipment. The flat, dark blue color

> very adequately serves to eliminate reflected light from other operating components which might be seen on the front glass surfaces of the indicator oscilloscopes. Such reflections would interfere with proper operation of the radar equipment in these two rooms, the ceiling lights of which are turned off during operations.[282]

Actual construction for the system of ADCCs and ADDCs began in 1949-1950, with buildout continuing into 1956. There were 16 air defense command posts (ADCCs) operating in the continental United States as the program transitioned to SAGE in the late 1950s. The Air Force built two more in Alaska and four in foreign countries (Canada, Japan, Spain, and Germany). The ADCC, each responsible for a multi-state (or, large geographic) region, became a key tenant associated with no less than six ARDC and Air Materiel Command installations: Griffiss (experimental and Syracuse Air Force Station), Hanscom (experimental), Kirtland, Norton, Tinker, and Wright-Patterson. Tinker would sustain an especially long and important air defense mission, with an ADCC and ADDC built together on a segregated site adjacent to the base (see Volume I, Part IV). The North Truro Experimental ADDC, coordinated by the Cambridge Research Center with Project Lincoln (in early efforts toward SAGE), was operational in 1952. Typically, Cambridge and Rome orchestrated interior improvements to the ADCCs and ADDCs period as retrofits to the original buildings. Like the underground plant project, the late 1940s ADCC and ADDC were evocative of the unusual role filled by Air Materiel Command for special civil engineering problems. The ADCC and the ADDC were the first true command centers of the Cold War.

Special Studies Office, Air Installations Division, Wright-Patterson

Air Materiel Command's project for an underground pilot plant and for the command posts needed for ADC's first permanent national air defense web represented the rich civil engineering role undertaken by the command as the Army Air Forces transitioned to an independent Air Force during the late 1940s. Another as yet unverified civil engineering project of the period likely overseen by Air Materiel Command was the first Cold War B-36 hangar. The unusual hangar was a Z-D short-barrel structure designed and engineered for SAC by Anton Tedesko in May 1947.[283] SAC constructed the hangar only twice (at Rapid City [Ellsworth] and Limestone [Loring] Air Force Bases), but planned to erect it in many multiples, including clusters of two and three hangers at Wright-Patterson. The Tedesko B-36 hangar was another truly notable civil engineering achievement. SAC, like ADC, was often a major tenant on ARDC and Air Materiel Command installations in its role of strategic alert as of the late 1950s (see Volume I, Part IV). In this era, Air Materiel Command appears to have had the responsibility of supporting the air installations (civil engineering) function at Headquarters Air Force in Washington, D.C., and was specifically assigned

special problem sets for new buildings of the Cold War. Many of the immediate challenges of innovative structures continued to focus on protective construction. SAC, for example, did not establish its own Protective Construction Branch at Offutt Air Force Base in Omaha—within the Directorate of Civil Engineering, Headquarters SAC—until 1960.[284]

Formalization of the civil engineering role within Air Materiel Command of the earliest Cold War years occurred in 1950 and is epitomized in the establishment of the Special Studies Office at Wright-Patterson. The Special Studies Office followed upon the founding of the AFSWP Protective Construction Committee during late 1947 and early 1948. The AFSWP Protective Construction Committee included five members, with one each from the Air Force, Army, Navy, Atomic Energy Commission, and the AFSWP itself. The Director, Air Installations—again, Headquarters Air Force civil engineering—designated the Air Force delegate to the committee.[285] As of FY1949, the Air Installations Division participated in "three high-priority projects associated with the Atomic Energy Program...with the personnel and the funds already available to the division."[286] The initial mission of the subsequent Special Studies Office at Wright-Patterson was "to handle civil engineering problems of a difficult or unusual nature throughout AMC...[and also provide]...engineering support for Air Force participation in nuclear field tests."[287] The unique office also "performed studies and investigations of many problems including airfield pavements, aircraft hangar designs and concepts, aircraft revetment studies, and sonic boom studies and investigations."[288]

Key to the Special Studies Office was the Air Force Protective Structures Program. The two-man team of Lieutenant Colonel Bert E. Petit and civilian Louis A. Nees began the program, pioneering efforts toward the analysis of the effects of nuclear explosions on structures. Air Materiel Command contracted with the Armour Research Foundation in Chicago for shock studies simulating nuclear blast. To manage the contracted research and test, the command turned to the engineering department at the University of Cincinnati. Air Materiel Command hired Eric H. Wang, then teaching mathematics there, to monitor the research contracts channeled through the Special Studies Office and to soon become its head. Mr. Wang was an Austrian engineer who had immigrated to New York City in 1938 to avoid the rising changes of Hitler's Germany. Wang had moved to Cincinnati in the early 1940s, and had been a faculty member at the university since 1947. The Protective Structures Group within the Special Studies Office participated in its first full-scale nuclear weapons testing during the 1951 atomic detonations of Operation Greenhouse in the Marshall Islands. For those tests, Mr. Wang analyzed data as it came in and wrote follow-on reports. The group had four team members by this date: Petit, Nees, Wang and Roman Birukoff. Mr. Birukoff was a Russian immigrant of pre-World War II. He had achieved his engineering degree at New York University in 1932 and had worked for the federal government since 1939.[289]

At Wright-Patterson, the Special Studies Office remained obscure within the bureaucratic structure, which was reflective of the emerging role of sophisticated R&D civil engineering for the Air Force and of the advancing work of the Protective Structures Group. Period telephone books for the installation suggest that the office existed within the Planning and Design Section of the Air Installations Division for Headquarters Air Materiel Command during 1950, with a shift to the Installations Engineering Section within the same hierarchy by the next year. As of early 1953, Mr. Wang's group was subsumed within the Engineering Branch, Air Installations Division. Not until late 1954 did the base telephone books reflect the presence of the Special Studies Section of the Engineering Branch within the Air Installations Division.[290] During that year, the Special Studies Section managed the Air Force contract with the Armour Research Foundation for a 150-foot long, six-foot shock tube built in Gary, Indiana, for wave propagation research to simulate nuclear effects.[291] By mid-1955 and into late 1956, nuclear protective studies became paramount for the Special Studies Section, with Mr. Wang transferred to the Mechanics Research Branch of the Aeronautical Research Laboratory.[292] During 1955, the special civil engineering group also shifted

from Air Materiel Command to ARDC. The Special Studies Section then became the Blast Effects Research Group. By autumn 1956, ARDC relocated the "special studies office" to Kirtland as the Structures Division, Research Directorate of the Air Force Special Weapons Center (AFSWC), with Eric Wang in charge. Mr. Birukoff also relocated to New Mexico (Plate 59). As of early 1961, a permanent Air Force Shock Tube Laboratory was operational as an associated facility at Sandia, neighboring Kirtland and run under contract through the University of New Mexico (and later renamed the Eric H. Wang Civil Engineering Research Facility and, subsequently, the New Mexico Engineering Research Institute [NMERI]).[293] The Air Force dismantled the Armour Research Foundation shock tube in Gary, shipping it to New Mexico for reassembly (see Volume II, Chapter 8).

Within the 1950 to 1956 period, the Special Studies Office managed research for both "unusual" and protective structures, with the latter focused on nuclear effects analysis. While little is known, as yet, regarding the specifics of the studies contracted under Eric Wang's leadership, at least one example serves to illustrate the probable magnitude of the engineering expertise involved. In early December 1952, Air Materiel Command, through the Special Studies Office of the Installations Engineering Branch of the Air Installations Division, contracted with German architect Konrad Wachsmann at IIT in Chicago for the design of an aircraft hangar. Previously, Wachsmann had aided the War Department and the NDRC in providing detailed wood moisture analyses for the German urban residential structure built at the Dugway Proving Ground to test the development of the napalm incendiary bomb during 1943-1945. In 1944, he had applied for a formal patent for the design of a double-cantilever spaceframe hangar, working in partnership with Hungarian engineer Paul Weidlinger. Both men were internationally renowned, and Weidlinger would go on to become a premier expert in the engineering and assessment of structures hardened against nuclear effects. Between 1941 and 1945, Wachsmann also had worked in partnership with Walter Gropius, a former leader of the Bauhaus who was then teaching at Harvard. Wachsmann and Gropius had patented a prefabricated house system through the pair's General Panel Corporation. The Wachsmann and Gropius patent was almost simultaneous with the Wachsmann and Weidlinger hangar patent. In1946, Wachsmann developed his "mobilar structural building system," appropriate for large halls and, especially, aircraft hangars.[294] In early 1949, SAC's commander General Curtis LeMay listed General Panel Corporation prefabricated housing as his first choice to alleviate shortages at SAC bases. General Panel offered its 640-square-foot house to SAC at a price of just under $2,000 per unit.[295] (SAC would also look at other manufacturers of prefabricated housing and commissioned an all-steel dormitory from Detroit Steel Products in 1951.) The 1952 R&D contract with Air Materiel Command is likely a direct continuation of Wachsmann's futuristic designs for aircraft hangars of 1944-1946. It is a follow-on to the engineering achievement represented through the double-cantilever hangar designed for the B-36 by the Kuljian Corporation in 1951—the preliminary specifications for which were very likely tied to the middle 1940s work.[296] Wachsmann was a professor in the Institute of Design at IIT as of 1949, joining the German expatriates Mies van der Rohe, Walter Peterhans, and Ludwig Hilberseimer on the faculty. IIT had also received one or more Paperclippers through the Department of Commerce by 1948, although no names are yet researched.[297] Wachsmann continued teaching at IIT through 1964. Thereafter, he was a faculty member of the University of Southern California until his retirement in 1973.[298] (The General Panel Corporation manufacturing plant, post-World War II, was in Los Angeles.)

The Air Materiel Command liaison with Konrad Wachsmann ran between December 1952 and May 1954 under contract AF33(600)-22947, with close-out discussions into April 1955. In a preliminary action, the Directorate of Installations, Headquarters Air Force, requested copies of the plans and specifications for the five variants of the Kuljian double-cantilever hangar from the Army Corps of Engineers during June 1952 "[i]n connection with the recently authorized design and construction program for AMC"[299]—at once alluding to a connection between Kuljian double-cantilever hangar of

Plate 59: Eric H. Wang (left) with Roman R. Birukoff, Kirtland Air Force Base, 1957. Courtesy of the History Office, AFRL, Kirtland Air Force Base.

1951, the Wachsmann prototype work of 1944-1946, and yet another try for the futuristic hangar desired by Air Materiel Command. The architect's first progress report in early 1953, for what the command called the "Unusual Hangar Design" (and alternately, "the Wachsmann type hangar"), discussed making models to test the "three dimensional characteristics of this space frame design."[300] Mr. Nees, then chief of the Installations Engineering Branch, forwarded the Wachsmann progress reports to the Director of Installations at Headquarters Air Force in Washington, D.C. Nees cited Eric Wang as in charge of the contracts with Wachsmann and IIT. By mid-1953, slight cost over-runs on the $50,000 contract were occurring, although IIT continued to prepare project drawings and requested a several-month extension to the 10-month original contract.[301] Of note, during early 1953 Air Materiel Command also had contracted with Kuljian Corporation a second time for the design of a very large overhaul hangar for the B-52. The overhaul hangar, built at Kelly Air Force Base in San Antonio and planned for Robins Air Force Base in Georgia, was a double-cantilever structure that was 2,000 feet long and 300 feet wide, erected in five modules using a double-hinged system. The timing of the Wachsmann and Kuljian contracts in 1953 suggests that Air Materiel Command either integrated elements of Wachsmann's spaceframe cantilever into the technical specifications provided to Kuljian, or that the command had hoped to do so. The situation is extremely similar to that defining the Kuljian contract for the original double-cantilever hangar of 1951.[302]

In March 1954, the Directorate of Installations notified Air Materiel Command that Wachsmann was to complete the drawings for his "design principle to [a] double cantilever hangar;" "[c]omplete [a] model of connectors and pipe to permit study of erection procedures and illustrate use of [the] design principle for various structures;" and, "[p]repare a brochure explaining [the] principle, erection procedure and application." Headquarters decided to close out the project, further noting that although the 1952-1954 Air Materiel Command contract with Wachsmann was for $50,000, the government had spent a total of $130,000 so far on the prototype design—again implying that the "Wachsmann hangar" was a longer-term project.[303] The final report on the project, in mid-May 1954, noted that the tubular space frame, as applied to the double cantilever, required complex stress analysis and testing through the Armour Research Foundation in Chicago. The Air Force put the Wachsmann hangar on hold and collected a project inventory from the architect that included aluminum parts and steel die casts; a plastic model of the hangar, 11 by 14 by 3 feet, set on a wood-and-masonite base 16 by 14 by 5 feet; an unfinished "metal" model of the hangar; wooden model airplanes; and, several books—including *Jane's All the World's Aircraft* (1951-1952 and 1952-1953). As of April 1955, Headquarters, Air Installations, requested that Air Materiel Command retain the plastic model of the hangar, the set of aluminum connectors, and the steel die casts for a possible subsequent look at the proposed technology.[304]

Structures Division, Air Force Special Weapons Center

With the late 1956 shift of the Special Studies Office to Kirtland as the Structures Division, Research Directorate of the AFSWC, the focus of the civil engineering cadre under Eric Wang concentrated almost entirely on engineering to withstand nuclear effects. One of the very first examples of research projects handled by Wang for the Structures Division was one analyzing the *Effects of Topography on Shock Waves in Air*, which was a contracted assessment through Broadview Research and Development of Burlingame, California (A.B. Willoughby, Kenneth Kaplan, and Richard I. Condit). The ARDC shock-wave study was a part of Project 1080, a multi-year endeavor entitled *Protective Construction and Target Vulnerability*.[305] Efforts during the 1950s were strongly linked to contracted R&D, particularly through selected universities and research corporations. Throughout most of the decade, Air Force-supported research on the effects of atomic, and then thermonuclear, weapons included a majority of contracts affiliated with institutions or companies in the Illinois-Ohio region, with Air Materiel Command, and then ARDC, in charge of the interactions. The key contracted participants were the Armour Research Foundation in Chicago, MIT, the University of

Illinois in Champaign-Urbana, the American Machine & Foundry Company, and E.H. Smith & Company. As of about 1960, contracted R&D for the analysis of nuclear effects on structures broadened to include more research companies and universities, with these shifting to an emphasis in the West and Southwest—with the sustained exception of the University of Illinois.[306]

From the beginning, a fundamentally important tie existed between an Air Force civil engineering understanding of the effects of nuclear weapons and a professor at the University of Illinois, Dr. Nathan M. Newmark. Dr. von Karman had chosen Dr. Newmark to write a section of the fourth volume in *Toward New Horizons* in 1945. The volume, *Aerodynamics and Aircraft Design*, included Newmark's contribution, "Aircraft Materials and Structures," which was perhaps the earliest look at the role that materials would play in the era ahead. Dr. Newmark, teaching at the University of Illinois, was also serving as a civil engineering authority within von Karman's R&D advisory group, SAG. As of mid-1952, MIT hosted a conference on *Building in the Atomic Age*, where each of the approximately dozen engineering authorities on the subject presented a paper. Dr. Newmark delivered "Analysis and Design of Structures Subjected to Dynamic Loading." The volume of articles derived from the conference served as a prototypical design manual for this type of specialized civil engineering, with inclusion in the technical library at the AFSWC at Kirtland.[307] Over time, Dr. Newmark would work for the Air Force through contracts to the Civil Engineering Department at the University of Illinois and through ones directly to his own firms (N.M. Newmark, Consulting Engineering Service and Newmark, Hansen and Associates).

By 1957-1958, ARDC concentrated efforts toward an analysis of nuclear effects at the Special Weapons Center. In October that year, the AFSWC hosted the 14th meeting of the Panel on Blast Effects on Buildings and Structures, and Protective Construction, which resulted in a volume of printed material (as had been the case in 1952).[308] In 1957, the center managed a contract with Paul Weidlinger for the design of a protective alert shelter for the B-58, running the study for SAC. The contract marked Weidlinger's entry into the analysis of nuclear effects on structures—a role his firm, Weidlinger Associates, Incorporated (WAI), would sustain for the Air Force into the early 1990s.[309] As of 1958, Dr. Newmark was writing formal design and engineering manuals addressing nuclear effects on structures, with *Protective Construction Review Guide*, volume 1, prepared for the Office of the Assistant Secretary of Defense, Properties and Installations.[310] In August, Newmark, Hansen and Associates conducted an on-site survey of a SAGE facility to "determine the feasibility of in-place hardening."[311] As Task Number 10802 of Project 1080, Dr. Newmark coauthored the first edition of the *Air Force Design Manual: Design of Protective Structures to Resist the Effects of Nuclear Weapons* with a colleague at the University of Illinois, Dr. J.G. Hammer, in 1959. Five additional senior and junior staff members of the Department of Civil Engineering at the university contributed to the threshold-breaking document. *Design of Protective Structures* had

> intended use...for planning and designing structures to resist the effects of nuclear weapons ranging into the Megaton class. The emphasis is primarily on underground construction. The material presented is derived from existing knowledge and theory, so that the manual is also a report of the state of the art.[312]

Drs. Newmark and Hammer discussed

> free-field phenomena in air and ground, material properties, failure criteria, architectural and mechanical features, radiation effects, surface openings, conversion of free field phenomena to loads on structures, and the design and proportioning of structural elements and structures.[313]

Simultaneous with the first edition of *Design of Protective Structures* at the close of 1959, the civil engineering mission within the Air Force, and especially as associated with Wright-Patterson and ARDC, quickened. A fledgling education for civil engineers within the Air Force had been in place at Wright-Patterson since 1949, paralleling the establishment of the Special Studies Office. During the 1950s, the School of Installations Engineering primarily trained officers for staff engineering positions. As of 1953, the school included a Base Civil Engineer course that allowed officers to explore a probable college direction in civil engineering, but did not substitute for that education. Most coursework was introductory. By 1960, the situation changed. The Base Civil Engineer course load included 237 hours of class held over 37 weeks within the Civil Engineering Center, with about 10 percent of the topical work focused on nuclear effects.[314] As of 1960 also, the Civil Engineering Center at Wright-Patterson initiated publication of the official Air Force journal for civil engineering, *Air Force Civil Engineer*. The seven Air Force Regional Civil Engineer offices which had originated only as liaison units to the Headquarters Directorate of Installations during the early 1950s had become fully established too[315]—taking over the role largely handled by Air Materiel Command during the 1945-1955 period. In addition, by 1960-1961, certain commands within the Air Force moved toward more civil engineering independence. SAC established its own Protective Construction Branch (as noted above) and the Air Force Ballistic Missile Division (AFBMD) in Los Angeles did the same. SAC required hardened infrastructure, while AFBMD's Civil Engineering Office had the challenging task of designing oversight for above- and underground missile facilities[316] (again, with many contracts carried forward by private-sector engineering firms working with the Air Force civil engineers). As an example of the latter, AFBMD directed the design and construction of Space Launch Complex 36 at Cape Canaveral for NASA's Atlas-Centaur during 1961-1962[317] (see Plate 1). The movable steel gantry was an internationally recognized engineering achievement, and was the work of Anton Tedesko (see Volume I, Part II). Once more, this strongly suggests that Tedesko worked continuously throughout his American career with the Army Air Forces and the Air Force, from 1940 forward without break—and that the link originated through Materiel Command at Wright Field, sustained over time through connections to civil engineering within Air Materiel Command and ARDC / AFSC.

These changes of 1960-1961 did not lessen the role filled by the Structures Division of the Research Directorate at the AFSWC. Although Eric Wang died in 1960, the Structures Division went forward. The next year the Air Force Shock Tube Laboratory was operational at Kirtland, run through the University of New Mexico. The facility was subsequently renamed the Eric H. Wang Civil Engineering Research Facility (alternately known as CERF). When AFSC reorganized research components of the AFSWC as the AFWL in mid-1963, the Structures Branch continued within the AFWL. By late 1963, the Air Force decided to expand the mission of protective construction studies (1956-1963) to become "a consolidated civil engineering research and development program"[318]—a purpose extremely similar to that of the original Special Studies Office for Air Materiel Command at Wright-Patterson during 1950-1955. In October 1963, the AFWL prepared a detailed study for the Research & Technology Division, AFSC, entitled *Proposed Plan for the Establishment and Development of a USAF Civil Engineer Research Capability*. The proposal compared the desired role of the Structures Branch at the AFWL to the existing engineering research, development, testing, and evaluation roles present at the Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi, and, at their Engineer Research and Development Laboratory at Fort Belvoir, as well as at other Army laboratories. The proposal also compared the work of the Structures Branch to that of the Naval Civil Engineering Laboratory (NCEL) at Port Hueneme, California. Like the civil engineering endeavor within Air Materiel Command and ARDC / AFSC, the NCEL had begun at an eastern location at Solomons, Maryland (comparable to the Special Studies Office at Wright-Patterson) and had moved to the West, 60 miles north of Los Angeles (comparable to the relocation at Kirtland within ARDC.[319]) The document further noted that the Air Force civil engineering research functions remained without a true "centralized responsibility" in one location.[320] In mid-1964, the

Structures Branch at the AFWL became the Civil Engineering Branch, functioning as the AFSC laboratory for civil engineering research. By the close of 1966, the AFSC designated the AFWL as the key laboratory and manager of contracted R&D for "all civil engineering exploratory and advanced development, as well as the development of criteria for design of protective structures." Five sections comprised the Civil Engineering Branch of the AFWL: Protective Structures, Facilities Technology, Experimental, Special Projects, and the CERF. The sustained manning of the first four sections was about 80 percent military and 20 percent civilian. The University of New Mexico's CERF was entirely civilian staffed.[321]

During the 1960s, the rise of the civil engineering mission at the AFSWC, and subsequently within the AFWL, was steady and meteoric. In late 1962, Dr. Newmark updated the *Air Force Design Manual Principles and Practices for Design of Hardened Structures*, again with the participation of colleagues in the Department of Civil Engineering at the University of Illinois. The second edition of the manual featured long, detailed chapters addressing air blast phenomena, free-field ground motion, structural loads, the dynamic properties of materials, structural failure, properties of structural elements and design criteria, design of individual structural elements, earth shock and shock mounting (particularly important to the first ICBM launch complexes in design at this time), nuclear radiation, architectural and other considerations, a theory of structures, and design examples. Among the latter were ones including buried arches and domes.[322] During the whole of the decade, the Air Force channeled its civil engineers working on problems of nuclear weapons effects to formal graduate study with Dr. Newmark at the University of Illinois. There Dr. Newmark used his *Principles and Practices for Design of Hardened Structures*, with appropriate updatings, to teach the key course on the subject. About 40 students were in the semester course, which was nicknamed "Bombs Away." The AFWL hand-picked its engineers from the University of Illinois, after they trained with Dr. Newmark. These students closed the circle of teaching and training for Air Force protective construction by running refresher courses at the AFWL using Dr. Newmark's manual.[323]

The Civil Engineering Branch at the AFWL continued to conduct key research for Air Force civil engineering into the early 1970s. The branch continued to be particularly focused on research for hardened structures. Test ranges for actual experimentation included several in New Mexico and adjacent to Kirtland. The AFWL also erected prototype structures on the UTTR affiliated with Hill Air Force Base in Utah. Simultaneously, related munitions testing went forward on the ranges at Eglin for hardened structures in design (See Volume II, Chapters 4, 6 and 8). Efforts at the AFWL were many and sophisticated. Research and tests ranged from those associated with the next generation of air defense command and control (the North American Air Defense Command [NORAD] facility in Cheyenne Mountain as well as the SAGE center at North Bay, Ontario, Canada—both built into existing hard-rock mountains) to those for missile silo engineering, design, and construction. A very large, multi-generational hardened aircraft shelter program also ran from the middle 1960s into 1992 (see Volume II, Chapters 4, 6 and 8). As of June 1972, the general civil engineering function moved from the AFWL (including the remaining components at Wright-Patterson) to a new Air Force Civil Engineering Center at Tyndall Air Force Base in Florida. The R&D for the design and engineering of structures capable of functioning in a nuclear weapons environment remained within the AFWL at Kirtland, sustained there throughout the Cold War period. AFSC controlled the Civil Engineering Center into 1977, whereafter the Air Force removed the mission from the command's jurisdiction and reassigned the center to the Air Force Engineering and Services Agency.

A Collegiate Plan for Modern Science Laboratories

Immediately paralleling the full-fledged status of an independent Air Force in mid-1947, yet another issue arose that was tied specifically to the needs of modern R&D. By 1952, ARDC understood that

research, analysis, and testing had unique construction needs separating the command from the larger Air Force—even from its originating command, Air Materiel. ARDC noted that its responsibilities to establish "the basic plant for research and development" supporting the aeronautical sciences required that ARDC achieve the "proper design of such non-standard structures as laboratories, wind tunnels, and engine test stands," as distinct from the "construction of normal airfield facilities." Headquarters ARDC in Baltimore suggested to the Deputy Chief Staff for Operations that such specialized architectural and engineering design across the installations of ARDC would be paramount during 1952-1955, and that contracted private-sector architectural-engineering firms, rather than a full-scale endeavor within civil service, offered the appropriate path to success. Of course, the approach of Headquarters ARDC closely followed that already well underway by Air Materiel Command during 1947-1951. For ARDC, however, the needs were short-term, focused most intensely before the mid-1950s, while the sophisticated civil engineering efforts initiated within Air Materiel Command ran the duration of the Cold War. As pointed out by ARDC, "each Center must be provided the facilities required for research in a specific general field." Headquarters ARDC recommended contracting a single architectural-engineering firm for each of its centers to handle these highly focused design needs.[324] Such contracting, generally, was not for the whole of the base but for clusters of specialized R&D facilities tied to its key ARDC mission. Laboratory groupings and technical facilities were particularly good candidates for this type of design when built during the intense period of the late 1940s and early 1950s.

Within ARDC the nine major centers under its umbrella at the outset of the command included:

- the WADC at Wright-Patterson in Ohio;
- the AEDC at Arnold in Tennessee;
- the Air Development Center at Holloman in New Mexico;
- the Flight Test Center at Edwards in California;
- the Missile Test Center at Patrick in Florida;
- the Armament Center at Eglin in Florida;
- the AFSWC at Kirtland in New Mexico;
- the Cambridge Research Center at Hanscom in Massachusetts; and,
- and the RADC at Griffiss in New York.

A tenth center was also important for its planning of the late 1940s and early 1950s:

- the Aerospace Medical Center at Brooks in Texas.

Brooks, however, would not be subsumed within AFSC until 1961. Each of the centers required specialized R&D facilities (see Plates 16 and 17).

Each situation was different, largely due to the existence, or lack, of established laboratories and test facilities on site. The size of the base at Wright-Patterson, as well as the installation's established ties to aeronautical R&D, precluded hiring a single architectural-engineering firm there. The missiles installations were also not reasonable candidates for single architect-engineer design. Early on, the firms responsible for developing the missiles often handled design of launch complexes and static test stands (sometimes through subcontracting for individual facilities). By the middle 1950s, contracting for missiles infrastructure fell to the WDD and its follow-on the AFBMD. This administrative decision caused the distinct rise of engineering firms based in Los Angeles, in part due to their physical proximity to the aeronautical industry. Only around 1954 do the firms in Southern California begin to sustain a repeated role in architectural-engineering design for ARDC, with the firms before this date clustered in the Detroit-Chicago and Boston-New York areas. Key Los

Angeles firms for missile complexes included Holmes & Narver; Daniel, Mann, Johnson & Mendenhall (later known as DMJM); and, Ralph M. Parsons. DMJM handled complexes of the middle 1950s at both Vandenberg and Patrick, while Holmes & Narver undertook a *Feasibility Study for a Guided Missiles Center* for Holloman in 1956—a center that shifted to Vandenberg, where Holmes & Narver handled Atlas complexes before the end of the decade.[325] While Holmes & Narver had been responsible for the test structures erected in the Marshall Islands for Operation Greenhouse in early 1951 and Ralph M. Parsons had developed the study for a hot-agent test site at Eglin the next year, these efforts were highly unusual. The mid-1950s Holmes & Narver study for Holloman, on the other hand, was precisely the type of "single-architect" contracting that ARDC had proposed in 1952.

A comprehensively designed technical facility for aeronautical R&D, distinct from missiles infrastructure, had its origins in the evolution of state-of-the-art science laboratories connected to universities during World War II. German university support for clustered academic science laboratories also reinforced the physical planning model of the mid-1940s. After the war, a literal explosion of both university and corporate science laboratory "campuses" established a pattern during 1945 to 1951. Indeed, by the time Headquarters ARDC voiced its requirements for single-architect complexes at its installations, a collegiate plan for modern science laboratories was at its peak. The notion of this type of organized campus layout, with buildings designed and planned by architects of well-known standing, affected about half of the ARDC installations in some way. Those not shaped by a collegiate laboratory plan were Wright-Patterson, Patrick, Holloman, Eglin, and Edwards, with Kirtland somewhat of an anomaly. In each case, except those of Wright-Patterson and Eglin, either ARDC did not complete the installation's laboratory groupings until the late 1960s, with planning no earlier than the middle 1950s, or, it saw intended laboratory complexes overshadowed by large-missile test launch facilities. (By the middle 1950s, the phenomenon of mini-campuses of science laboratories was beginning to wan, such that an appearance as of this date usually indicates earlier formal planning.) At Eglin, ARDC hired a single firm, Kellex of New York (renamed Vitro as of 1951), to develop an all-encompassing master plan for armament test facilities. Kellex scaled down the laboratory requirement to one large structure, first planned as attached to the armament hangar on the flightline.[326]

The earliest Air Force exposure to a collegiate laboratory model was at Edwards, through Dr. von Karman. The Jet Propulsion Laboratory had originated in 1936 as a part of the applied mechanics program at the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT) in Pasadena. The laboratory was on the campus grounds itself. Although not designed in the modern architectural spirit of 1945 forward, the Guggenheim Aeronautical Laboratory was an academic enterprise of the highest order. Associated static test stands for rocket engines were nearby, in the Arroyo Seco canyon of the San Gabriel Mountains, until the Edwards test complex replaced them. The linkage of a rocket test facility to a university laboratory set the stage for the direction suggested by Dr. von Karman as of the middle 1940s. The surge in academic laboratory complexes immediately after World War II reinforced the physical form that the Air Force laboratories for R&D would assume.[327] No actual laboratory cluster graced the Edwards site, although the Air Force did convert an early 1950s military dormitory grouping near the test stand area on Leuhman Ridge for use as a Science and Engineering Center in about 1963.[328] The test stand area did feature an *ad hoc* cluster of R&D buildings from about 1952, but with a mixed use of laboratory, test stand, high-bay missile assembly, and components storage—the antithesis of the collegiate laboratory cluster. Mixed-use construction was also typical for other test facilities at Edwards.[329]

The situation was quite different at Kirtland. For the AFSWC, ARDC first built a set of three double-cantilever hangars, not laboratories. The command configured the hangars with four adjacent support buildings for the bombing mission of the 4925th Test Group (Atomic).[330] Full expansion for a cluster of science laboratories did not occur until the middle 1960s, when research components of the center

evolved into the AFWL. By this very late date, the collegiate model for a laboratory cluster was two decades old, and a "laboratory complex" more often appeared as highly specialized laboratories built one after the other in proximity, but not as a uniform scheme. At Kirtland, the nucleus for a laboratory group dated to 1956, with construction in two distinct stages. Over more than 15 years, laboratories went in place, beginning with a Nuclear Weapons Research Laboratory group. Added in the early 1960s was a second Nuclear Effects Research Laboratory complex, with planning and construction staggered late in the decade. The two areas stood side by side and included classrooms, dormitories, and a technical library. The whole of the laboratory area also reused several World War II structures on site. The 1956-1958 grouping, not surprisingly, carried forward the idea of a collegiate laboratory plan more pristinely than did the neighboring cluster of the 1960s (see Volume II, Chapter 8).[331]

Each of the other ARDC installations incorporated a laboratory grouping differently, dependent on when actual planning and construction occurred. While the Air Force's earliest R&D plans most closely adhered to the academic collegiate prototype showcased in architectural and engineering journals of the day, the laboratories designed and built after the formal designation of ARDC in the very early 1950s were those that best represented the model. The Engineering Division of Air Technical Service Command prepared a schematic plan for a laboratory complex generically titled the Air Engineering Development Center in December 1945. This was the very earliest of Air Force R&D laboratory site plans[332] (Plate 60). The Air Engineering Development Center would not evolve into the AEDC at Tullahoma, Tennessee, until the outset of the 1950s. The December 1945 Air Engineering Development Center plan, however, was a very important one. The "first" AEDC included a full complement of laboratories, very close in its intended function to the R&D center suggested by the RAF to the United States Air Forces Europe, who in turn had passed the idea along to Air Technical Service Command at Wright-Patterson just the month before. The RAF-envisioned center was proposed as a nucleus for the study of confiscated German military equipment and technologies, with a possible location in the Boston area. In addition, the RAF suggested that Air Technical Service Command model the center after the German R&D "campuses" of the Hermann Göring Institute at Brunswick and the Kaiser Wilhelm I Institute at Göttingen—the latter affiliated with a major university.

As built in the early 1950s, the AEDC did not sustain its site plan of 1945. While the complex did feature a rectangular set of street grids, with a half-oval entry drive at the head of the grouping and plentiful spacing between buildings, a test and development mission using highly specialized wind tunnels, engine test cells, a gas dynamics facility, and other research chambers replaced the "laboratory" mission of six years earlier with one much more purely industrial.[333] A single engineering firm, Sverdrup & Parcel of St. Louis, did manage the A-to-Z endeavor, subcontracting selected individual buildings out to other architectural-engineering firms. Sverdrup & Parcel had previous industrial experience through the Army Air Forces. The firm had sustained immediate ties to Air Materiel Command through Leif Sverdrup's service in the Army Corps of Engineers in the Pacific and engineering-design work with J. Gordon Turnbull for the World War II bomber modification plant in Tulsa (Air Force Plant [AFP] 3).[334] Air Materiel Command initiated Sverdrup & Parcel's contract as site surveys for the AEDC. The firm conducted the surveys at multiple locations in the United States during 1947-1948. ARDC continued a liaison with the firm during the actual planning at Tullahoma in the early 1950s. After construction, only the street grid continued to allude to the original collegiate plan of 1945.

The Air Force next attempted to apply a collegiate laboratory plan to a self-contained complex at an R&D installation that would not come under the umbrella of ARDC until the outset of the 1960s—Brooks Air Force Base in San Antonio. The design process for Brooks was especially long, and extremely complex. Between 1926 and 1931, the Air Corps School of Aviation Medicine had operated at Brooks, in a single building. In 1931, the Air Corps had moved the school to Randolph

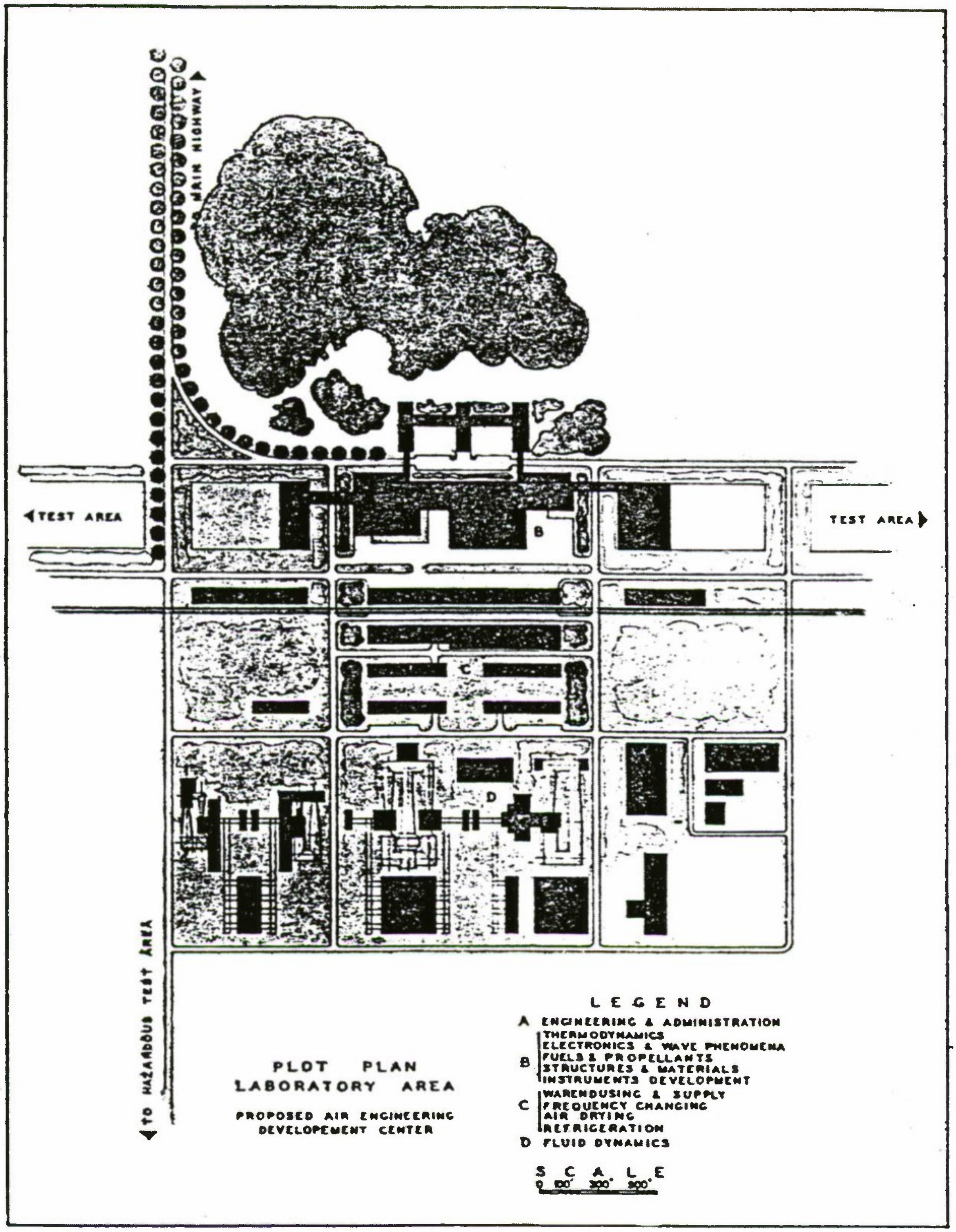

Plate 60: Proposed Air Engineering Development Center, 1945. In *Proposed Air Engineering Development Center*, 10 December 1945.

Field, another installation in the same city. At the close of World War II, the Army Air Forces once more looked to Brooks for the siting of an expanded School of Aviation Medicine. Stimulation for a new institution was directly tied to the displacement of the large group of German doctors whom the Army temporarily established during 1945 and 1946 at the Aeromedical Center in Heidelberg. That group, led by Dr. Hubertus Strughold, was a priority for the Army Air Forces under the Paperclip program, with the desire to build a state-of-the-art aeromedical center to support Dr. Strughold's continuing work in the United States. With the legality of the Heidelberg Aeromedical Center questionable, the Army Air Forces initiated studies in August 1946 for the improved stateside facility. In December, the Air Surgeon at Headquarters Army Air Forces, Brigadier General Malcolm C. Grow, proposed an Aero Medical Research Center to the commanding general of the Army Air Forces. General Grow included a variety of site considerations derived from an analysis of existing military hospital facilities and airfields over the past months. Included in Grow's analysis were three major suggestions for the needed center: Pratt General Hospital near the Miami Air Depot, Florida; the Veterans' Hospital at Fort Logan, Colorado; and, the McCornack General Hospital in Pasadena, California. Two of these, the Pratt and McCornack, were converted hotels. General Grow also discussed 12 rejected sites for an Aero Medical Research Center in Indiana, Connecticut, Massachusetts (at what would become Hanscom Air Force Base), New York (two), Virginia, Delaware, Tennessee, Georgia, Illinois, Ohio, and Nebraska.[335] As of March 1947, the tentative selection was Brooks Field, a subinstallation of Randolph at the end of World War II.[336]

Conflicting studies nonetheless continued throughout 1947 to 1949. As of the close of 1947, the School of Aviation Medicine at Randolph Field made new suggestions to the Air Surgeon for the location and design of an aeromedical center. Randolph proposed the transfer of the United States Navy Hospital in Houston, near Ellington Field and the Texas Medical Center, to the Air Force. This facility had opened in September 1946 and featured a sprawling U-shaped, late Moderne-style hospital, sitting at the head of a landscaped 118-acre tract. Construction was not yet completed for the 20 buildings planned at the site[337] (see Volume II, Chapter 2). Although transfer of the Navy hospital in Houston was rejected, planning for a collegiate laboratory cluster of medical buildings continued slowly during the late 1940s. Some stalling may have occurred while the Air Force resolved the basic placement of aeromedical R&D within one, or more than one, command. Simultaneously, the Army Air Forces moved Dr. Strughold's group to the United States, splitting them between Air Materiel Command's aeromedical laboratory at Wright Field and the School of Aviation Medicine under Air Training Command at Randolph. During 1947 and 1948, Dr. Strughold's group continued their research at Randolph, holding symposia for their American colleagues there as they had in Heidelberg during 1945-1946. At the close of 1948, Randolph's School of Aviation Medicine addressed space flight at one of these symposia, with a Department of Space Flight established in 1949 under the direction of Dr. Strughold, and staffed by Paperclippers Fritz Haber, Heinz Haber, and Konrad Buettner.[338]

In June 1949, Headquarters Air Force set up an Aeromedical Planning Board based on a recommendation of General Grow, indicating that the site selection process for a new aeromedical center was still far from resolved. Ten men held positions on the board, six from the School of Aviation Medicine at Randolph, three from the Office of the Surgeon General in Washington, D.C., and one from Headquarters, Air University, at Maxwell Air Force Base in Montgomery, Alabama. By this date, both the Armed Forces Medical Advisory Committee (alternately known as the Hawley Committee) and the Hoover Commission had favorably reviewed the basic project.[339] In a report of 1 September 1949, the Aeromedical Planning Board noted the gravity of the situation. The board commented that while the Army had about 16 general and major hospitals, and the Navy had 26, the Air Force was also dependent on these facilities. Randolph hosted the only active Air Force institution to train flight surgeons. The 1947 selection of Brooks Field apparently had been only tentative, with Brooks one of 12 sites assessed from among War Department installations "on a

weighted desirability comparison for modification." By autumn 1949, the preferred installation for adaptation as the Air Force aeromedical center shifted to the Naval Hospital in Corona, California. Air Force Surgeon General Grow recommended against the Corona choice.[340]

The Aeromedical Planning Board also described a high-cost, "ideal aeromedical center" proposed for an entirely new site. The idea had a price tag of over $155 million and featured more than 1,000 buildings at a pristine location. The Air Force anticipated that adding an "adjacent flying field" would require another $12.5 million in the budget. Total personnel was thought to approach 6,000, with 369 of these personnel working directly at the aeromedical center itself. The Air Force interpreted the ideal center as "dispersed laboratories grouped according to their relationship to each other." As of this report, the Air Force strongly desired independence in its medical research, with no Army or Navy participation in its center. The Aeromedical Planning Board summed up Air Force needs as substantive, focused on the challenges of future space flight.

> The Center would have the capabilities to research detectable, predictable, and of [*sic*] preventable diseases peculiar to aviation, also to study and advance the knowledge of flight in space, altitude, speed, acceleration, and human reaction control.[341]

With the outbreak of the Korean War, planning moved forward. In July 1950, the Air Force Chief of Staff recommended that the proposed Aeromedical Center be located adjacent to Randolph (at Brooks).[342] Not until early 1951, did the Air Installations, Headquarters Air Force, in conjunction with Major Harry G. Armstrong (the Air Force Surgeon General who followed Malcolm Grow), implement the project. By this date the Air Installations at Headquarters Air Force and the Office of the Surgeon General were coordinating review and comment on an architectural-engineering contract for an aeromedical center. Air Materiel Command, Wright-Patterson, had charge of the architectural-engineering contract, working with the Army Corps of Engineers in a pattern appearing to parallel the process for the air defense command-and-control buildings that the command had managed for CONAC during 1948-1949. As of March 1951, Air Materiel Command contracted with the Minneapolis firm of Ellerbe & Company for a master plan for the center, with drawings completed in July 1952. Air Materiel Command correspondence on the contract, No. AF 33(038)231170, implies that the master plan was still somewhat generic, but that the Air Force had told Ellerbe & Company to use "Brooks Air Force Base as a typical site." In November 1951, the Air Force committed to the selection of Brooks as the location for its Aeromedical Center, after "the near completion" of the Ellerbe & Company master plan. At that juncture, Air Installations, Headquarters Air Force, authorized Air Materiel Command to issue a separate contract for a general master plan to develop Brooks Air Force Base and to augment its contracting with Ellerbe & Company for continued work on an aeromedical center at the base.[343] The Aeromedical Center at Brooks compromised with the earlier notion of a pristine site and made use of vacant land at an outer corner of the existing installation.[344]

Work on the Aeromedical Center complex of laboratories continued into autumn 1953, with Ellerbe & Company additionally contracted to prepare "drawings, outline specifications, equipment schedule, and finish schedule"—in other words, to prepare the whole of the design for the center, including its site plan and its buildings.[345] By July 1953, Ellerbe & Company finished the drawings for the School of Aviation Medicine, Altitude Laboratory, Motion Laboratory, Research Laboratory Shops, Adaptable Laboratory, Power Plant, Research Institute, and the utilities. The Army Corps of Engineers forwarded them as preliminary and final definitives for Air Force review.[346] Design delays from the government made an extension of due dates necessary, with Ellerbe & Company completing the second increment of drawings for key buildings at the Aeromedical Center as of September 1953.

Air Installations commented in detail on the design of individual buildings, working back and forth with Ellerbe & Company. For the School of Aviation Medicine, for example, such revision was at its most active between the initiation of the building design and February 1953. The Air Force, presumably through Air Materiel Command, had prepared its "Technical Requirements, School of Aviation Medicine" in mid-October 1952 as the original basis for the design process.[347] Air Installations requested changes to the student assembly hall: in the type of motion picture screens in the auditorium (fixed, not motorized), placement of the conference room, and use of continuous exterior windows in selected locations, as well as basic room heights and widths.[348] The second stage of the project included the Administration and Clinic Building, Rehabilitation Clinic, and more utilities.[349] The total medical complex consisted of nine buildings.

During 1951-1953, while Ellerbe & Company worked on the design of the Air Force Aeromedical Center planned for Brooks, the firm also developed the definitive drawings for standardized hospitals for the Air Force. The hospital project appears to directly overlap with that of the Aeromedical Center, with hospital drawings substantially done by early 1953—but with a disputed cost overrun of more than $50,000.[350] The Army Corps of Engineers had the responsibility to issue and run the actual Air Force design and engineering contracts with Ellerbe & Company for both the Aeromedical Center complex of laboratories and for the Air Force standardized hospital. Numerical contract sequencing, DA 49-129-eng-131 and DA 49-129-eng-216, strongly suggests that the Corps issued the paperwork for both projects during 1949, with paperwork for the hospital earlier than for the Aeromedical Center. Ellerbe & Company was an established architectural-engineering firm with decades of experience in the upper Midwest. For the Air Force, the firm's chief professional recommendation for these particular assignments was its work for the Mayo Clinic in Rochester, Minnesota.[351] Dr. W. Randolph Lovelace II probably also influenced the choice of Ellerbe & Company for the design of a standardized Air Force hospital and the Aeromedical Center. Dr. Lovelace had worked at the Mayo Clinic in 1938 and had served in the Army Air Forces at Wright Field's Aero Medical Research Laboratory during World War II. His position on the SAG and at the post-war Lovelace Foundation in Albuquerque, as well as his authorship of the final volume on aviation medicine for *Toward New Horizons* in 1945, made any recommendation of Dr. Lovelace an important one. Association of the Aeromedical Center with a space medicine mission also lent the project grandeur and prestige.

The aeromedical center project continued to stall, with no site work until after mid-decade. Not until 1957 did actual construction for an aeromedical complex move forward at Brooks. By that date, the design of Ellerbe & Company was at least partially aborted, with a regional firm—Texas Architect-Engineers Association of Austin—selected to finalize design for the first six buildings and for the connecting underground utilities tunnels at what would become ARDC's Aerospace Medical Center. The Air Force designated these buildings as the Flight Medicine Laboratory, Research Institute, Research Laboratory Shops, Altitude Laboratory, Power Plant, and Academic Building (School of Aviation Medicine). These formal names match six of the nine among the completed Ellerbe & Company drawings of 1953, as does the reference to underground connective utilities. Two possibilities exist. The Texas Architect-Engineers Association may have merely spliced in the firm's name on the Ellerbe & Company drawings, taking over the job essentially as local construction managers. In this type of scenario, commonplace during the 1947 to 1960 period, the national-level architectural-engineering firm that was actually responsible for the design becomes "hidden." The Air Force had purchased the Ellerbe & Company drawings, and had authority to pass these documents on to another firm—also giving the firm hired for the job at the regional level the full right to "take credit" for the design. The alternate possibility is one of multiple coincidences, with the work of the Texas Architect-Engineers completely "new" in the middle 1950s. The likelihood, however, is that Aerospace Medical Center at Brooks, constructed during the middle and late 1950s, is actually a design of 1951-1953 (Plate 61).

The Air Force appears to have tried for a collegiate laboratory cluster at Brooks, as widely showcased in the private sector during the 1945-1952 years, but failed in its attempt at design follow-through. As of late 1959, a formal move of personnel began from the still-functional School of Aviation Medicine at Randolph Air Force Base, across town from the Brooks site. Another six structures did not go in place until 1961-1964. These buildings were of different design detail than those of Ellerbe & Company, understandably no longer having the same function as the buildings planned during 1949-1953. Fourteen years had passed from the initiation of the design process for an Air Force aeromedical complex, during which time needs in space medicine had advanced and changed. Ironically, the firm the Air Force hired to carry forward this second stage of work for the Aeromedical Center at Brooks was nationally prominent, like Ellerbe & Company. Smith, Hinchman & Grylls, of Detroit, completed the center in the early 1960s (Plate 62).[352] Smith, Hinchman & Grylls was also well known for the design of major medical centers, but their work generally emphasized a single, large multi-structure such as the Wayne University Medical Center in Detroit. This approach was distinct from that for the science laboratory, but was cutting edge for teaching hospitals, clinics and large medical research laboratories beginning in the late 1940s and firmly established by 1960.

Timing, and perhaps location, influenced the design of a collegiate grouping of science laboratories established for electronics and radar R&D at ARDC's two remaining installations of Hanscom and Rome. The command's timing for the commissions at Hanscom was nearly perfect, paralleling that for similar laboratory clusters at universities and private-industry research sites of the late 1940s. In the case of the Cambridge Research Center at Hanscom, ARDC's laboratory complexes were in the vanguard of such clusters designed anywhere. The commissions did not stall between conception in 1948-1951 and completion in 1951-1956. The Cambridge Research Station made a detailed and thorough study of the prominent laboratory clusters designed and built in the United States between the last years of World War II and 1951. The architectural firms selected for the Cambridge laboratories were excellent. Designers of the first two laboratory groupings included the Boston firms of Shepley, Bulfinch, Richardson & Abbott and Cram & Ferguson. In 1956, RAND erected a cluster of Butler buildings, in a distinctive layout, neighboring these laboratories. During 1958-1960, other architects and engineers added individual buildings to a fourth area that related to the other three. Finally, in 1959-1960, The Architects Collaborative at Harvard prepared an updated master plan for Hanscom as a whole. As this process was in progress, ARDC reused one of the early 1950s laboratory designs from Cambridge for a scaled-down version at the RADC (a single building). In this manner, ARDC's designation of Rome as a subinstallation to the Cambridge Research Center became not only appropriate in terms of mission, but also in terms of physical design. The laboratory clusters at Hanscom are the preeminent representation of a collegiate plan for R&D within the command. With the laboratories for the Cambridge Research Center, ARDC fully realized its planning and design process for a cluster of modern laboratories for scholars.

The three Boston architectural-engineering firms involved in designing the Cambridge and Rome laboratories brought significant design history to their efforts for ARDC. The Architects Collaborative was the architectural-engineering firm founded by Walter Gropius after his immigration to the United States in 1938. Gropius, the pre-war leader of the Bauhaus in Germany, achieved an unrivaled position in international architecture by the 1940s. Architectural critics, including the leading American critic Henry-Russell Hitchcock, had championed the work of Gropius early in his career. Hitchcock had labeled Gropius' design for a shoe-last factory in Germany of 1911 (the Fagus Works) as the most advanced representative of international architecture before World War II. ("Shoe lasts" are the wooden models of human feet used to shape shoes or boots during manufacture.) New York's Museum of Modern Art had likewise included the Fagus Works in its photographic exhibition and accompanying catalogue of 1932, *Modern Architecture*. In the 1920s, Gropius had united the remnants of the two design and applied arts schools in Weimar to found the Bauhaus. He pulled together some of northern Europe's finest architects, craftsmen, and artists to teach and work at

the institution. Simple rectangular buildings, emphasizing long horizontal bands of fenestration across full facades, showcased varieties of the glass curtain wall. At the Bauhaus, individual buildings were connected, meeting at right angles to form a single complex. By 1939-1942, when Mies van der Rohe (previously with Gropius at the Bauhaus) won the competition for the design of the new IIT campus in Chicago, the clean, rectangular forms had become discreet units. They were free-standing while still at right angles. Unadorned grassy plots sat between to emphasis the buildings' rhythm and spacings.

From the Bauhaus to IIT, the campus designs emphasized a low sweeping horizontality, with no individual building more than four stories high and others only two stories tall. In 1945, Gropius joined with seven other architects to form The Architects Collaborative: Jean Bodman Fletcher, Norman Fletcher, John C. Harkness, Sarah Harkness, Robert S. McMillan, Louis A. McMillen, and Benjamin Thompson. During 1949-1950, the progressive firm handled the design for the Harvard Graduate Center.[353] ARDC directly cited the Harvard Graduate Center as a model for the Cambridge Research Center of 1951[354] (Plate 63), calling out the design for special consideration by the architectural firms working on the Hanscom laboratories.[355] Regarding the design for the Harvard Graduate Center, ARDC told its architects: "A campus plan type laboratory group based upon the philosophy and design used here would make a very desirable center."[356] The command then turned to The Architects Collaborative directly for master planning needs at the close of the 1950s.

As early as 1948, ideas were simmering for the design of a state-of-the-art research complex at a new physical site. Personnel within the Cambridge Field Station initiated efforts toward this end just as Air Materiel Command was considering consolidation of the Watson Laboratories in New Jersey with the Cambridge Field Station—planning to place both at Griffiss as the new electronics center. Robert M. Barrett, the Chief of the Airborne Antenna Research Branch, suggested that a "local school of architecture be given a set of requirements for a research laboratory, to meet postwar standards for research in radio physics, geophysics, and related sciences." Mr. Barrett approached the Graduate School of Architecture at MIT, and informally arranged for an advanced design class to use "the design of an Electronics Research Laboratory" as its course project. Twelve graduate architecture students completed designs for the proposed laboratory. To carry out the project, the students responded to a comprehensive set of requirements and specifications prepared by Mr. Barrett on his own time. A discussion and review of the submittals culled the student designs to three. Both the Air Installations Division, Headquarters Air Force, and Air Materiel Command, Wright-Patterson, looked at the MIT graduate work. Internal Air Force review occupied the second half of 1948 into the spring of 1949.[357] Of note, correspondence between Air Installations, Headquarters Air Force, and Air Materiel Command acknowledged that Colonel Heath Twitchell of the Army Corps of Engineers had also suggested that the Air Force, Army, and Navy "explore the possibility of setting up special engineering projects for graduate study at various colleges" at this same time.[358] The MIT effort had been a collaborative one between professors and their graduate students. The head of the Department of Architecture, Laurence B. Anderson (of Anderson & Beckwith, a Boston architectural-engineering firm), and architecture professor Ralph Rapson, the former head of the Department of Architecture at the Chicago Institute of Design, were both closely involved in the project.[359]

While interest in the proposed Cambridge Research Center lagged during the remainder of 1949, as soon as the Air Force decided to stay in Boston rather than move to Rome, New York, planning moved forward. As of mid-January 1950, the Wright-Patterson Electronics Subdivision turned to one of the 1948 MIT graduate architecture student designs, coupled with the specifications prepared informally by Cambridge Field Station's Mr. Barrett, to complete budget estimates for the new complex. The selected student design and Mr. Barrett's specifications also became the basis for a command-prepared proposal issued to the private sector architectural-engineering community. The first budget for the Cambridge Research Center projected a total cost of about $8.5 million for

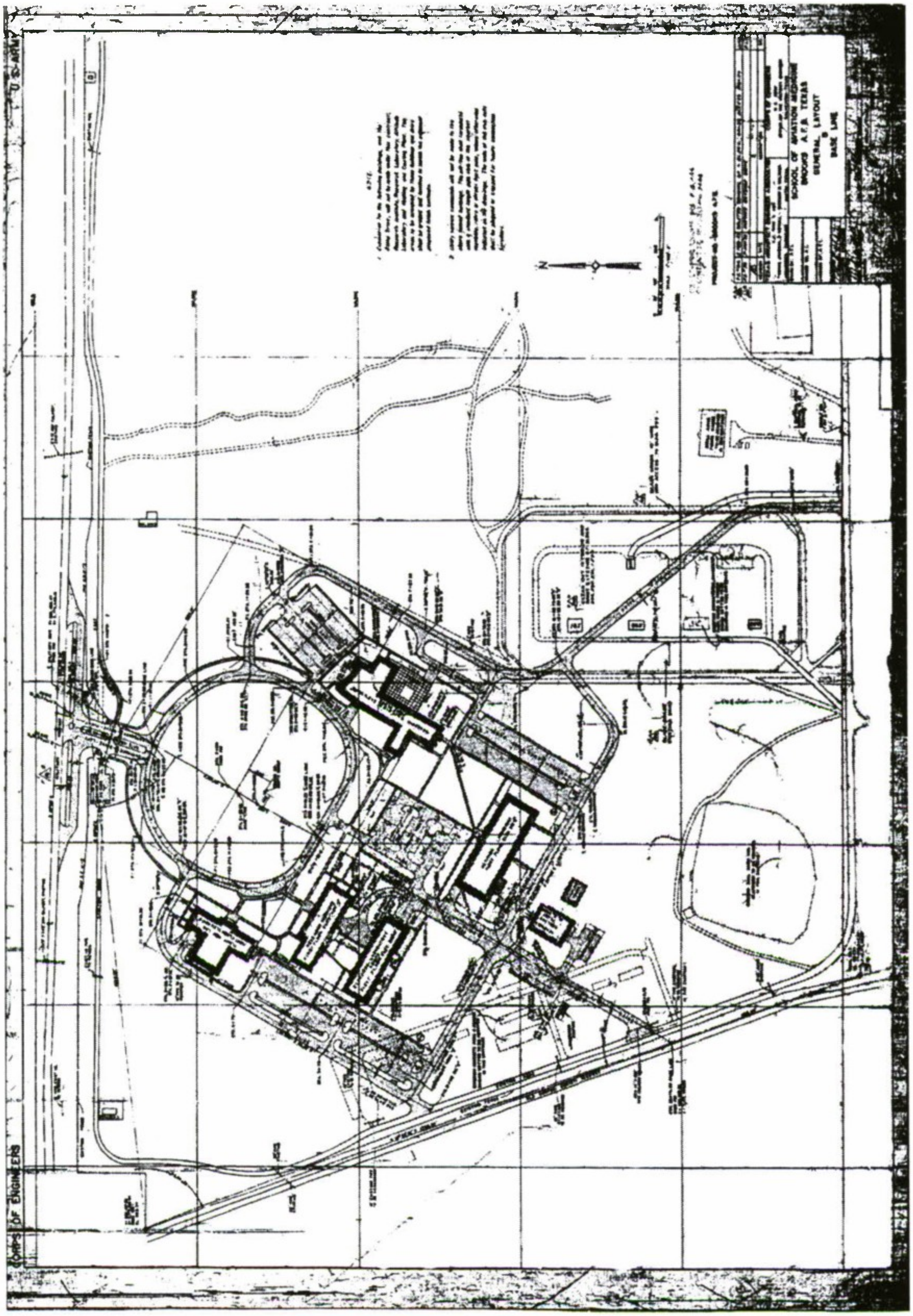

Plate 61: Texas Architect Engineers Association. School of Aviation Medicine, Brooks Air Force Base. General layout, December 1956 (Derived from a design of 1953 by Ellerbe & Company.) Courtesy of Civil Engineering, Brooks Air Force Base.

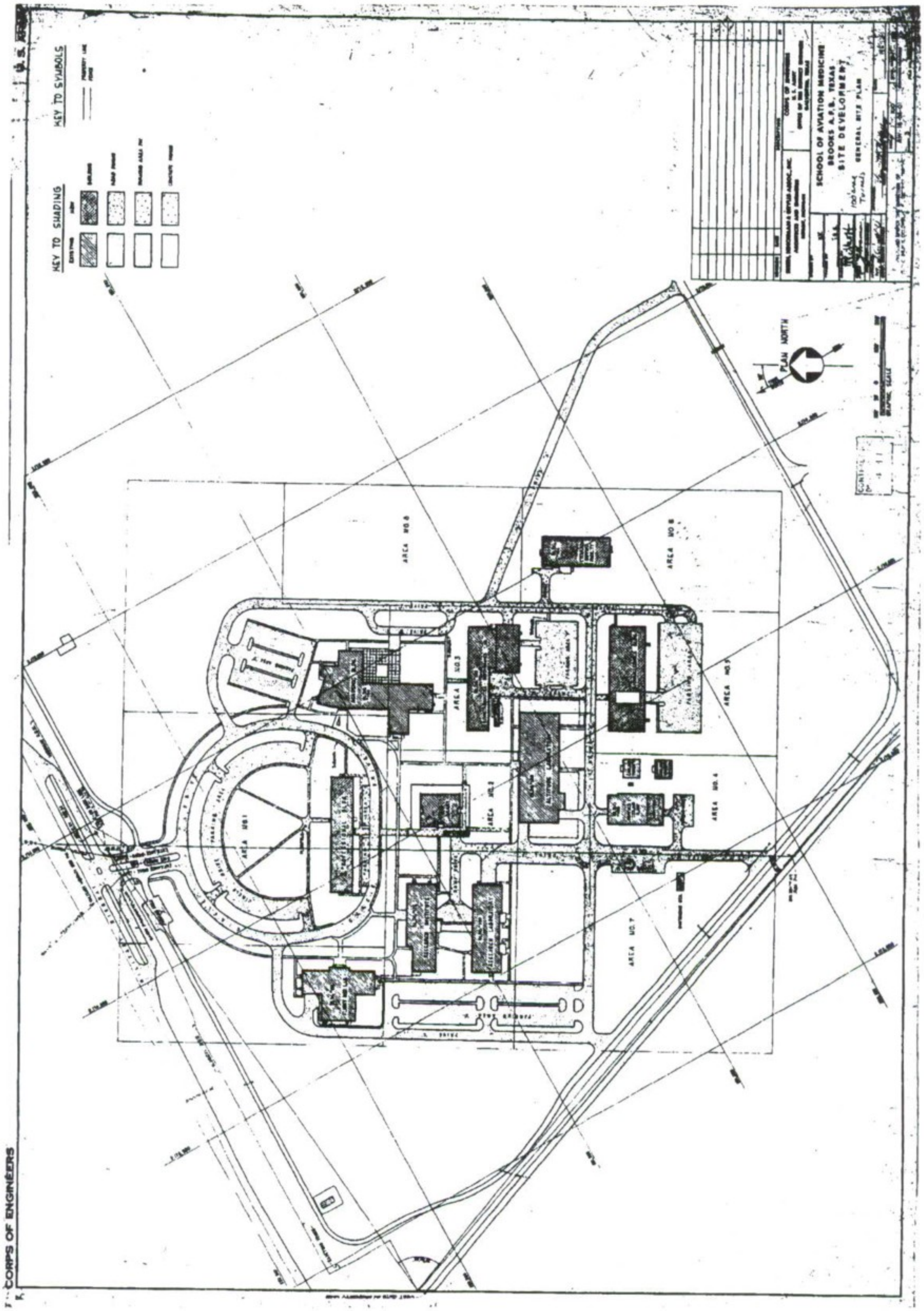

Plate 62: Smith, Hinchman & Grylls. Aerospace Medical Center, Brooks Air Force Base. Site plan, February 1961. Courtesy of Civil Engineering, Brooks Air Force Base.

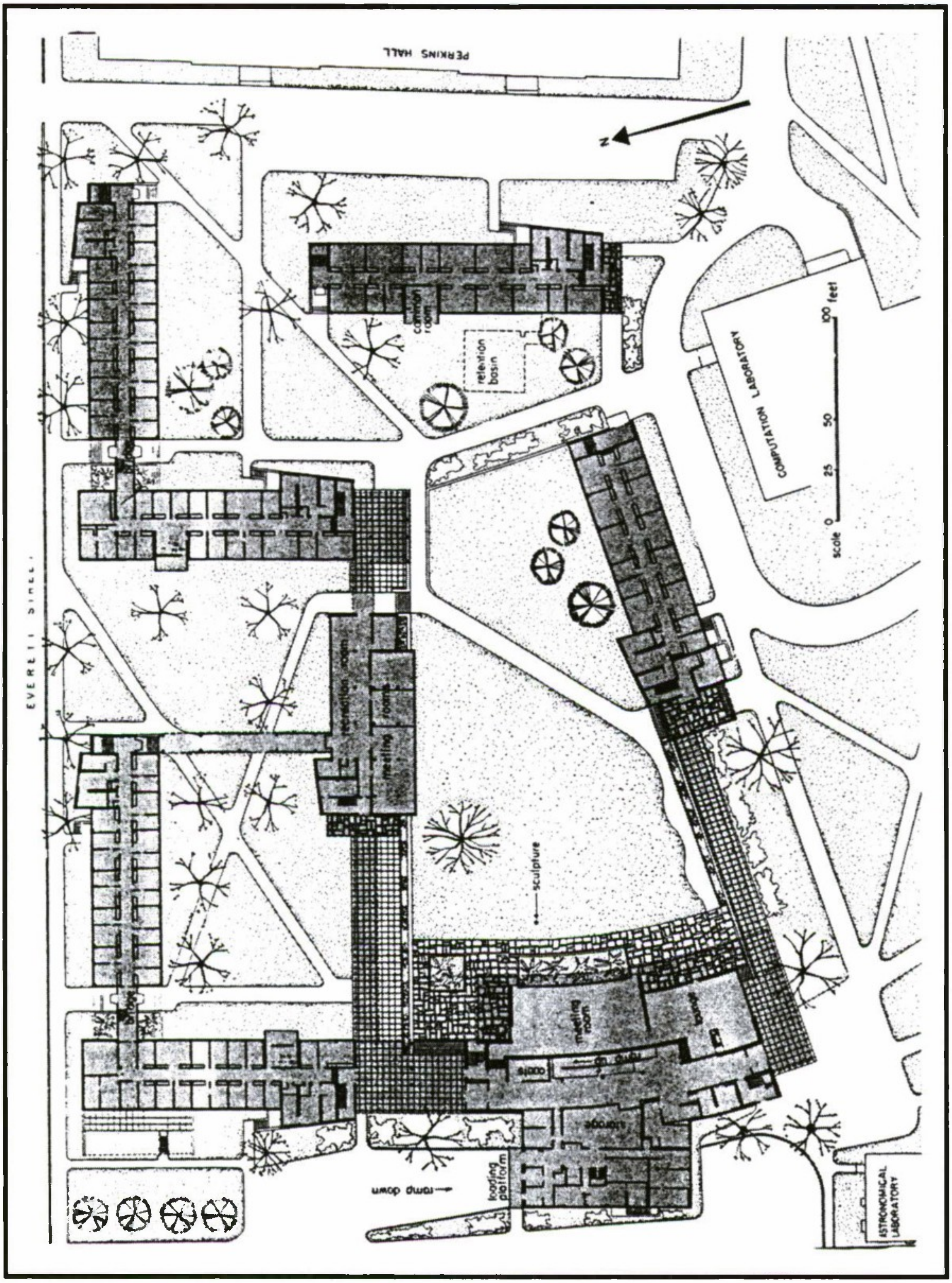

Plate 63: The Architects Collaborative. Harvard Graduate Center, Boston. Site plan, 1949-1950. In *Architectural Forum*, December 1950.

buildings. The laboratory complex-to-be was not yet a collegiate grouping of individual buildings. The chosen student design (identity not uncovered) was for a single 300,000 square-foot structure to serve as a joint main laboratory and administration building. The student's proposed laboratory was to meet the "needs of a fast moving science" and was to "be designed to provide extreme flexibility."

> It should be possible readily to change room sizes and laboratory layouts with the attendant relocation of laboratory services (telephone, wiring, gas, water, air, etc.), and the finished appearance of the laboratory should not be altered by such changes. It is believed that such flexibility will necessitate the use of the modular system of space allocation.[360]

The Barrett / MIT-designed laboratory was to have the maximum amount of "well controlled natural lighting;" be carefully heated and air conditioned; be very quiet; provide roof space for some research projects; and, be "flexible enough to allow for at least a 3 to one expansion of the laboratory." The Air Force would incorporate many features of this initial design into the final collegiate cluster, both in the individual buildings and in their master plan relationship to one another. As conceived in 1948, the laboratory was a single large building that included individual specialized laboratories (photographic, materials testing, standardization, potentiometer, and computing), a large auditorium, conference rooms, a museum, display rooms, a "first class technical library," modular offices, shops, service sections, and storage. The late 1940s laboratory design also featured a well-designed cafeteria. The specialized laboratories within the building featured a "basic working module of fifteen (15) feet by twenty-five (25) feet...adequate for a wide variety of laboratory research work." Even as early as 1948, and in the highly preliminary form of a student design based on internal Cambridge Research Station ideas, reference to the "[i]ntensive study of recently constructed research laboratories" was a paramount consideration for the planning of the new Cambridge Research Center. Mr. Barrett mentioned the Bell Telephone Laboratories in Murray Hill, New Jersey, and the Naval Ordnance Laboratories in Maryland. One specified quality of the Barrett / MIT cafeteria design, present in the final laboratory collegiate complex of laboratory buildings, is still notable today:

> It would be desirable if portions of the cafeteria could be isolated, say by a glass wall, so that small luncheon meetings could be held without the noise and confusion of the regular cafeteria.[361]

By March 1950, the Air Force had formally decided that the location for the new electronics laboratory would be in Bedford, Massachusetts, to make use of the existing Bedford Field (Hanscom Air Force Base). Congress approved an Air Force Research Complex, budgeted for FY1952 acquisition and construction. As of late January 1951, the Director of Radio Physics Research at the Cambridge Field Station, John W. Marchetti, selected Mr. Barrett to officially represent the laboratory in all discussions on the specifications and requirements for the center. Mr. Barrett attended design conferences between the Air Force and the architectural-engineering firm hired for the project. The Air Installations Division, Air Materiel Command, delegated the general responsibilities for exact location, construction type, and number of buildings to comprise the laboratory group to the commander of the existing Cambridge Field Station, but emphasized that all drawings and associated specifications would require review and approval from Air Materiel Command at Wright-Patterson. Air Materiel Command stressed that the Cambridge research project should address the possibility of a larger complex than first anticipated. Actual contract coordination was through the Army Corps of Engineers, again with a process paralleling that for other projects of the period. The selected architectural firm was Coolidge, Shepley, Bulfinch, & Abbott, a follow-on partnership to several long-distinguished Boston firms.[362]

Choice of Coolidge, Shepley, Bulfinch & Abbott at the outset of 1951 was preliminary. By the time the commission solidified in 1954-1956, the firm changed form slightly to Shepley, Bulfinch, Richardson & Abbott. The firm brought a lineage of excellence to the planning of the ARDC electronics research laboratory project. The grandfather firm behind Coolidge, Shepley, Bulfinch & Abbott was that of Henry Hobson Richardson, renowned for Trinity Church built in Boston during 1876. At Richardson's death in 1886, a number of his last commissions continued with his successor firm, Shepley, Rutan & Coolidge, including the design for the campus of Stanford University in the early 1890s. George F. Shepley, Charles H. Rutan, and Charles A. Coolidge also became prominent as American architects of the early 20th century. Their firm was responsible for buildings at Brown and Harvard Universities, and at the University of Chicago. These men, all of whom were on the drafting staff of Richardson, died in 1914, 1925, and 1936, respectively, and the firm continued with new partners and name changes. As of 1925, the firm became Coolidge, Shepley, Bulfinch & Abbott, with Henry R. Shepley—the son of George Shepley and one of Henry Hobson Richardson's daughters—entering the dynasty. This version of the firm continued into the middle 1950s, when it became Shepley, Bulfinch, Richardson & Abbott, with another family member entering the business. Coolidge, Shepley, Bulfinch & Abbott designed many medical complexes and laboratories, particularly ones on university campuses.[363]

Events continued to accelerate during 1951. By mid-February, the commander of the Cambridge Research Station, Colonel Hugh Mitchell, notified Air Materiel Command that an Air Defense Systems Laboratory, as a second and distinct complex, might double the overall laboratories planned. The air defense laboratory immediately assumed a high priority within the scheme for the Bedford site, with its distinct complex in the formative stages but planned to rapidly accelerate as a construction program. In correspondence between Colonel Mitchell and Air Materiel Command, ARDC was again looking at recently-built science laboratories, particularly those of General Electric, Bell, and RCA.[364] In every case, the recommendations for model laboratory complexes appear to have originated with Mr. Barrett and the MIT graduate student project. Late the same month, Colonel Mitchell set up a Station Planning Board to oversee a master plan for the "Air Force Cambridge Research Laboratories Establishment." Although a single, 300,000 square-foot laboratory building (that was now interpreted as three stories tall) still dominated ideas for the complex, some "functions" that earlier had been incorporated into the structure were now separate buildings. Henry R. Shepley, Mr. G. Richardson, and Mr. Bulfinch had represented Coolidge, Shepley, Bulfinch & Abbott at the first design meetings in late January, where the Air Force expanded the laboratory complex to include a supply warehouse, air installations (civil engineering) building, motor pool, power plant, fire station, and separate cafeteria. In addition, the laboratory master plan was to "be sufficiently flexible to incorporate any research and development activity assigned to that location." Mr. Barrett continued to participate in all design and planning meetings for the complex. The Air Force asked Coolidge, Shepley, Bulfinch & Abbott to prepare preliminary drawings for the Cambridge laboratory complex no later than about mid-March.[365]

The Cambridge Research Laboratories continued to guide the design process. Mr. Barrett prepared a critical *Program of Requirements* in April 1951. The *Program* was 250 pages long and included many detailed guiding ideas as well as illustrations of three "tentative laboratory design models." Mr. Barrett most certainly selected these photographed architectural models from those of the graduate architecture students at MIT (Plate 64). The *Program* also featured "A Typical Master Plan" for the individual laboratory groupings that was taken from the auditorium and creative arts center at Brandeis University. By May-July 1951, schematics toward the Cambridge Research Center evolved to include a much more comprehensive master plan which illustrated two collegiate laboratory groupings for the electronics research center at Hanscom, with the suggested cluster of ancillary buildings between them (warehouse, air installations, motor pool, and power plant) (Plate 65). The two groupings were those for an electronics laboratory center: six offset buildings, A-F, for

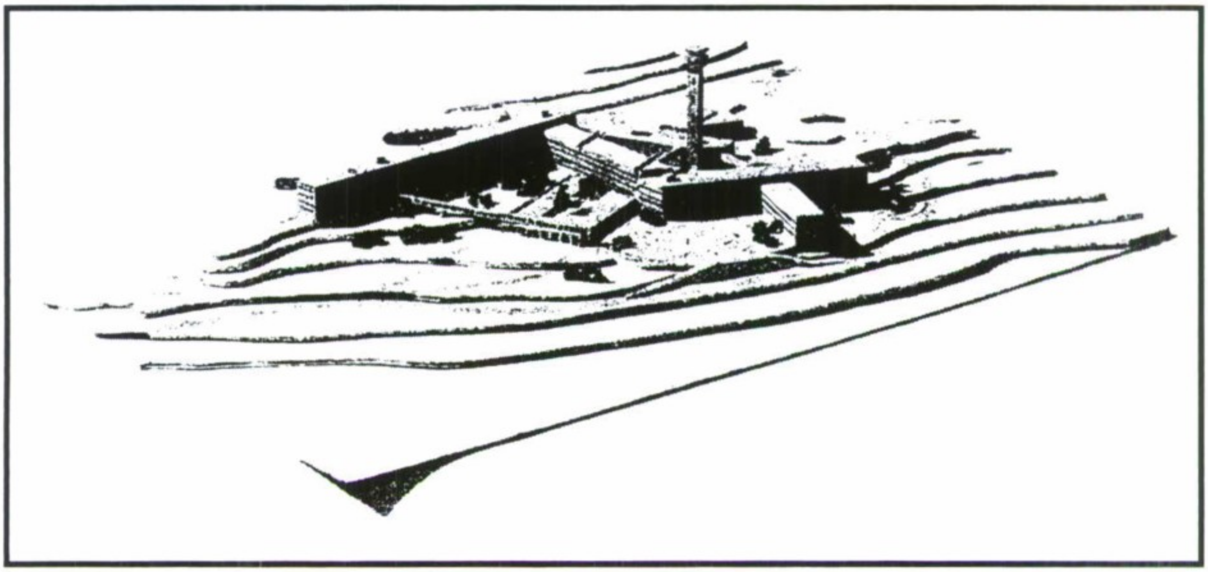

Plate 64: Massachusetts Institute of Technology, Graduate School of Architecture. Tentative Laboratory Design I [for the Cambridge Research Laboratories], 1948. In *History of USAF Cambridge Research Laboratories 1 April – 30 June 1951*, volume 1.

an Electronics Division and a Geo-Physics Division, coupled with a slightly segregated set of buildings for the Radio Biological Division; and six offset buildings, A-E, with one unlettered, for an Air Defense Division. Colonel Mitchell estimated the total cost of the mid-1951 Cambridge Research Center campus at $27 million, with an anticipated 3,000 laboratory personnel. Air Materiel Command, the Cambridge Research Center, and ARDC started the process for determining the basic specifications for the added Air Defense Laboratory while Coolidge, Shepley, Bulfinch & Abbott continued to work on drawings for one of the laboratory groupings. As of mid-1951, the Air Force was not fully satisfied with Coolidge, Shepley, Bulfinch & Abbott's designs. They asked the architects to concentrate on the modular and flexibility concepts requested, the fenestration and roof treatments, and achieving "the best contemporary style."[366] The architects began to redesign the laboratories. Again, Mr. Barrett appears to have had a leading role in the design process and insisted that the hired architectural firm follow his *Program* of April, in which he had also called the architects' attention to a detailed bibliography of scientific research laboratory complexes heralded in architectural journals from the 1942-1950 years.

The Air Force interpreted the Hanscom project as an opportunity for excellence. The agency argued that scientists performed better when "coddled" and when "working under attractive conditions—which develop naturally from harmony of design and fidelity to detail—broadly described as 'campus.' " Also forthrightly called out was the mistake of "nonhomogeneous structural groups," with Wright Field and the Naval Research Laboratory given as examples of what-not-to-do. Mr. Barrett disparaged these laboratory sites as having "various architectural styles which give the impression of having grown like Topsy." He emphasized that "it is necessary that a master plan be evolved which will result in a homogeneous integrated complex of structures and activities which will harmonize with each other and will possess a simple dignity."[367]

> Technical personnel strongly supported the argument that the Air Force had a golden opportunity to set new high standards in the design of the new Research Center, the first installation dedicated to a primary mission of research.[368]

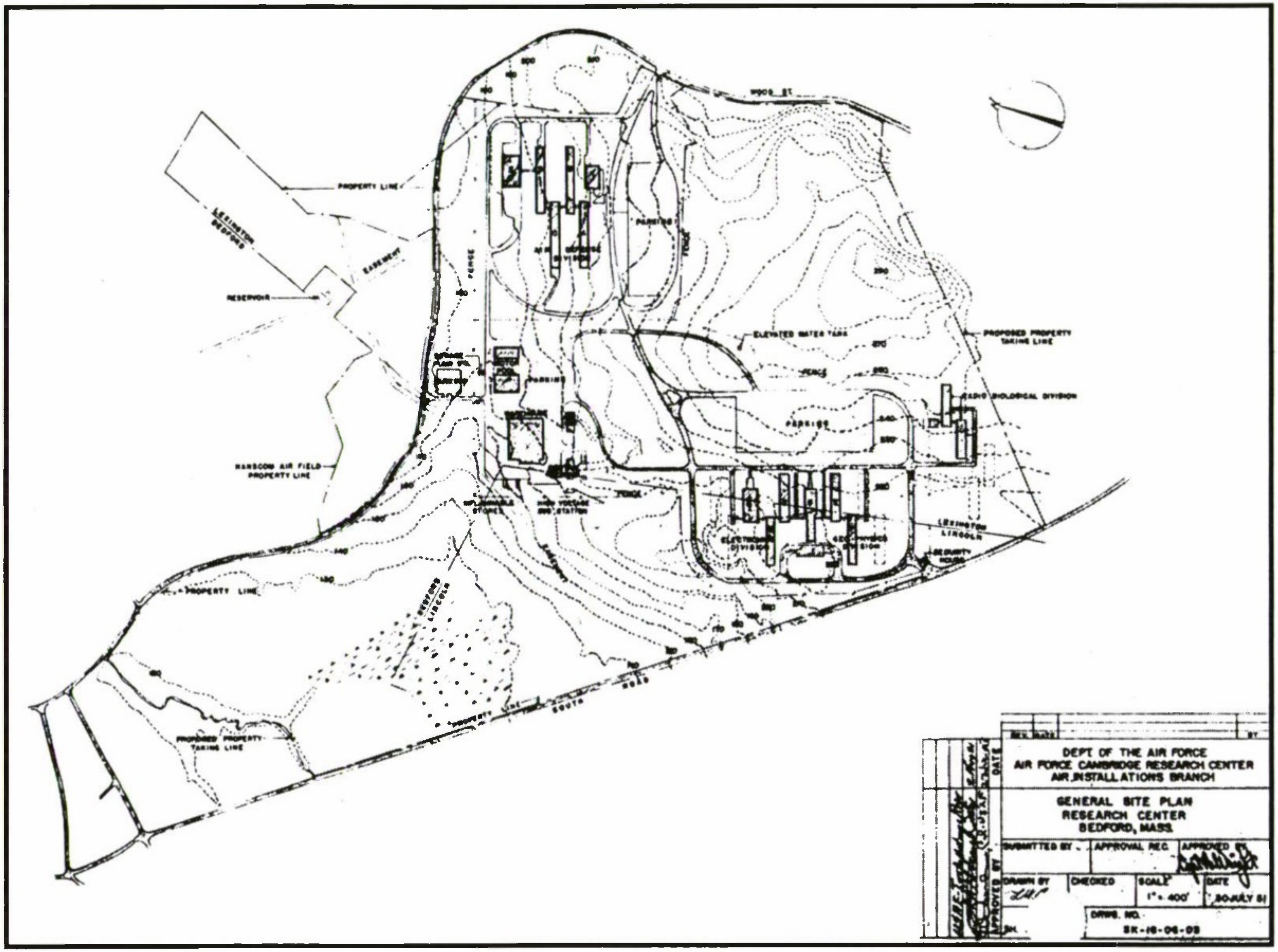

Plate 65: Cambridge Research Center, Bedford, Massachusetts. Site plan, July 1951. In *Air Force Cambridge Research Center 1 July – 31 December 1951*, volume 15, part 1.

The Air Force subsequently described Mr. Barrett's *Program* of specifications and suggestions as "sometimes expressed in highly technical form, sometimes in philosophical mood."

> [As] the Air Force warranted the best possible personnel for its high priority projects, it would be good business to provide pleasant and uncrowded working conditions, and the best of tools and equipment. The site at Bedford afforded both opportunity to get away from industrial dirt and gases, and room enough for a layout that would give freedom from...[various types of] problems.[369]

In Mr. Barrett's own words "it will be necessary to compete against the environment offered by the universities and by many of our private industries. This environment is in many respects built of intangibles on an esthetic of intellectual level."[370] To this end, Mr. Barrett included both references to, and explicit discussion of, the leading university and private-industry science laboratory complexes of the day. He sometimes suggested examples to emulate, as well as examples to explicitly avoid. The newness of a collegiate plan for military science laboratories, as epitomized at Hanscom in its 1948-1951 design process, is akin to the idea of a "campus" workplace for the emerging computer industry as developed by Microsoft in suburban Seattle in the late 20th century.

In the *Program of Requirements*, Barrett included a detailed bibliography of 45 articles from a range of architectural, professional, and popular journals including *Architectural Record*, *Architectural Forum*, *Progressive Architecture*, *Electronics*, *Chemical Age*, and *Popular Mechanics*. Each of the selected articles contained photographs and site plans that were intended to showcase a recent laboratory complex built in the United States, England, or, in a few cases, Mexico and South America. Architects designed some collegiate laboratory groupings for university campuses, but most were new clusters of science laboratories built on pristine sites for private industry. Barrett discussed seven international examples as representative of the architectural style appropriate for the Cambridge Research Center. These examples featured the science and pharmacy buildings at Drake University in Des Moines, Iowa (1947), the General Motors Technical Research Center on a 350-acre site near Detroit (1945-1946), and the Harvard Graduate Center (1950).[371] The architects in all cases were internationally known. For the Drake science and pharmacy cluster, two new buildings fit within an existing series of grassy quadrangles linked together and at right angles to one another[372] (Plate 66). The architect for the Drake commission was Saarinen, Swanson & Saarinen. After World War II, the administrators of Drake University, a college founded in 1881, consistently sought out the very best architects available for its expansion. During the period of the late 1940s into the middle 1960s, choices at Drake focused on Eero Saarinen and Mies van der Rohe. Saarinen's work at Drake included not only the science and pharmacy buildings (Ingham and Fitch Halls), but also four residence halls, a dining hall, and a religious studies hall—the full campus grouping featuring nine buildings erected between 1949 and 1957.[373] During these same years, Mies van der Rohe designed sequential buildings for the IIT campus in Chicago[374] (following the original plan). The work of both men was evocative of the best of the International Style. Barrett specifically called out the large expanses of horizontally banded glass windows and the interior color scheme in Saarinen's science and pharmacy buildings as exemplary.[375]

The General Motors Technical Center was also the work of Saarinen (Saarinen & Swanson). *Architectural Record* glowingly reported the Center as evocative of the future. The General Motors Technical Center was also strongly representative of Barrett's goals for the planned science laboratories at Hanscom.

> The much-heralded World of Tomorrow seems a bit less ephemeral with this vision of what one corporation promises in the way of

> research. ...This group of buildings...is designed to bring together the research and experimental facilities of the corporation, to bring about both a more rapid interchange of ideas and a closer contact between pure science and practical application...The Center will represent a purely fact finding and experimental activity.[376]

Barrett cited the bold master plan of the General Motors research facility as a model for the Cambridge Research Center.[377] Discussion of the other major examples was similar. In a final attempt to guide the design of the center, Barrett annotated his bibliography, starring some items of "especial interest." Among this group was the Federal Telecommunication Laboratories complex in Nutley, New Jersey, designed in 1946 by Giffels & Vallet, with L. Rossetti, of Detroit (Plate 67). This example was strikingly similar to one of the designs submitted by the MIT students: its futuristic 300-foot tower functioned as a microwave laboratory for antenna research[378] (see Plate 65).

Barrett's attention to detail in the *Program of Requirements* and his desire to shape the Cambridge laboratory complex closely to the work of the immigrant Bauhaus leaders is what sent Coolidge, Shepley, Bulfinch & Abbott back to the drawing boards in mid-1951. For fenestration, Barrett even offered examples of what was not acceptable. He cited the mid-1940s cases of the Firestone Research Laboratory in Akron, Ohio (Voorhees, Walker, Foley & Smith), and General Electric's Electronics Park in Syracuse, New York (Giffels & Vallet, with L. Rossetti). The comparison of desirable and undesirable juxtaposed the sweeping horizontal glass walls characterizing the designs of Gropius, Saarinen, Mies, and their fellow leaders in the International Style, and the more traditional punctuated horizontal bands of individual windows present in the Moderne style of the 1930s.[379]

> A curtain wall type of fenestration is required in order to provide a maximum of window area uninterrupted...This type of fenestration will not only provide the required daylight but will, if properly handled, provide a measure of flexibility of window treatment which will allow the window area to start at floor level or desk level and be varied at will depending upon the use to which the particular rooms are put.[380]

The collegiate plan, as sought for Cambridge, focused on a design by a single architect, with buildings spaced carefully in relationship to one another and with each featuring the most modern of individual stylistic details. Barrett was discerning enough to recognize that in some cases—and that of General Electric's Electronics Park was one such instance—the site plan could be a model for the future laboratories at Hanscom, while individual buildings were too conservative in style. *Architectural Record* had described Electronics Park in November 1945 as an "industrial group on the campus plan."[381] Barrett recommended against closely sited rectangular buildings, each parallel to one another, unless modulated through offsets. He also repeatedly emphasized the need for natural light.[382] In 1949, General Electric's facilities in Syracuse hosted a Test Operations Building for the Watson Laboratories (discussed earlier). General Electric and the Watson Laboratories used this structure for testing air defense command-post operations much as MIT would employ the Experimental SAGE building at the Air Defense Laboratory at Hanscom.

After mid-1951, two key laboratory clusters were underway for the Cambridge complex. The original grouping, in design by Coolidge, Shepley, Bulfinch & Abbott, continued to undergo revision, with final drawings dating to 1954-1956 as the architects absorbed the suggestions within the *Program of Requirements* and from the ARDC committees assigned to the project.[383] The finished cluster of laboratories for the Cambridge Research Center featured four main three-story buildings, staggered as two sets of connected rectangular wings, with a one-story building between them.

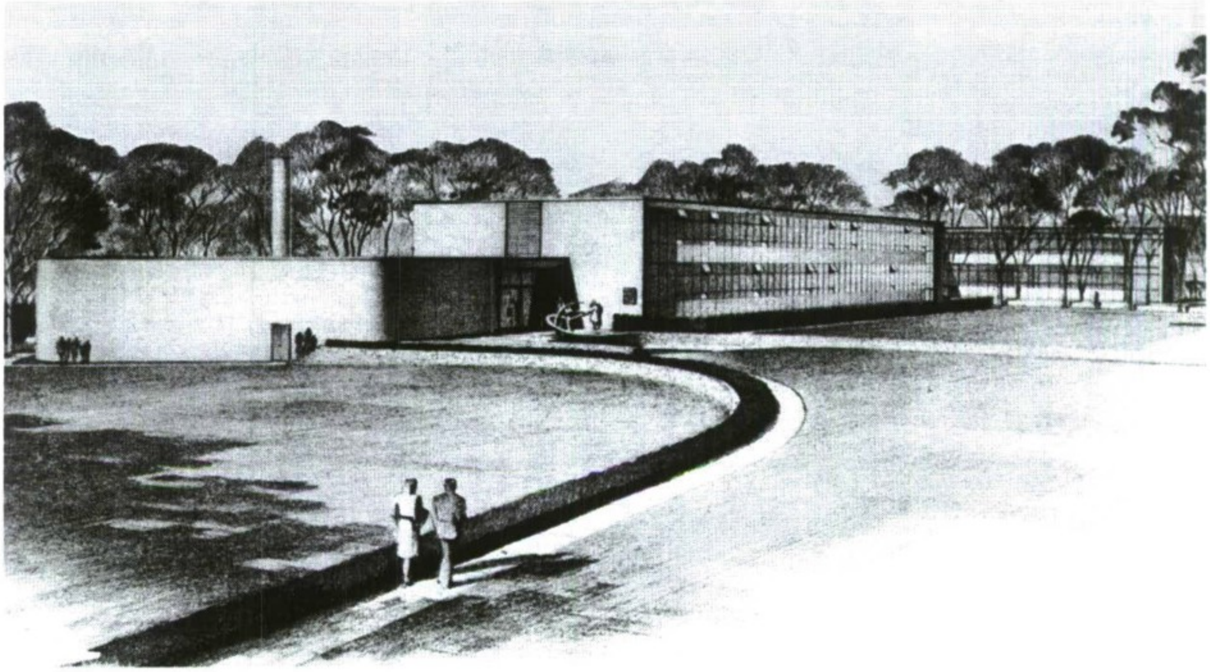

Plate 66: Saarinen, Swanson & Saarinen. Science and Pharmacy Laboratories, Drake University, Des Moines, Iowa, 1947. In *Architectural Record*, December 1947.

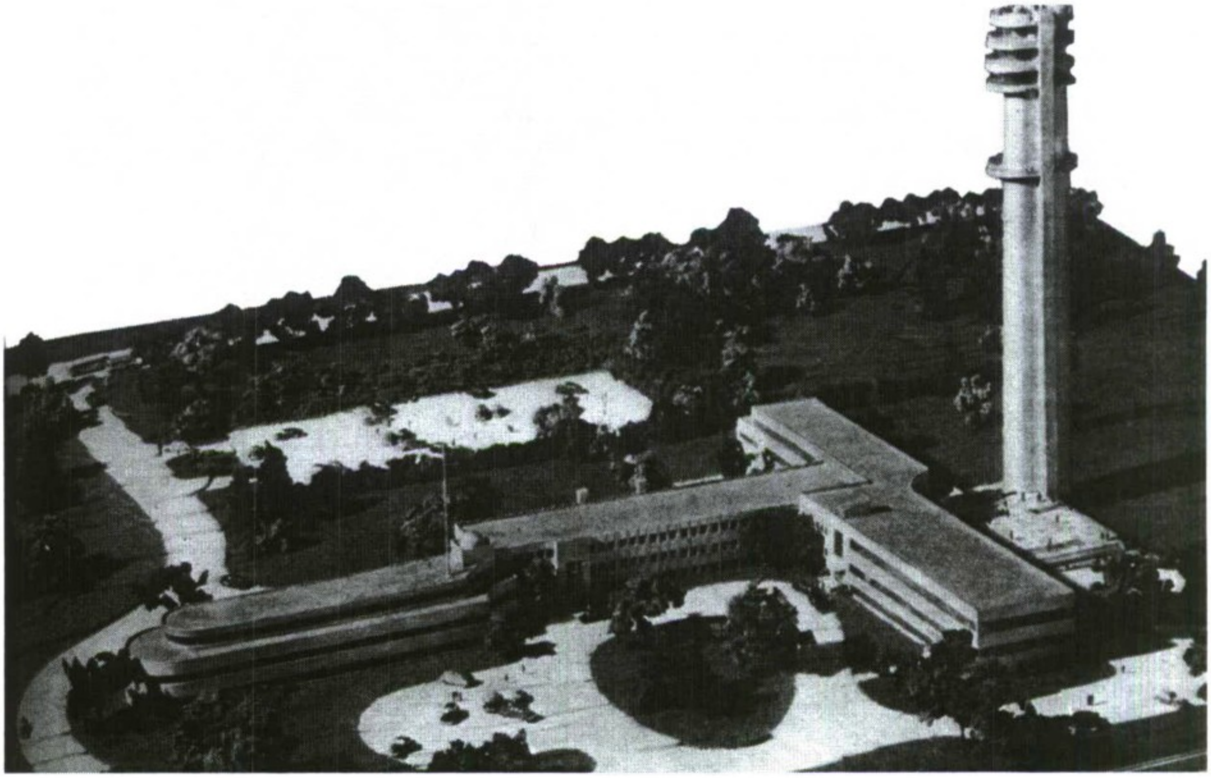

Plate 67: Giffels & Vallet, with L. Rossetti. Federal Telecommunication Laboratories, Inc., Nutley, New Jersey, 1947. In *Architectural Record*, January 1947.

Sizable open areas buffered the parallel structures (Plate 68). While work on the Cambridge research laboratories went forward, the Air Force commissioned another architectural firm, Cram & Ferguson, for the second cluster of laboratories on the site. MIT would operate these laboratories for Project Lincoln in the development of SAGE. The same design and siting parameters applied to the Air Defense Laboratory as to the Cambridge research laboratories, but work with the architects moved much faster. The quickened pace may have resulted from the lengthy discussions between ARDC representatives and Coolidge, Shepley, Bulfinch & Abbott. Project speed was also partly due to the prioritized air defense mission. By late December 1951, Cram & Ferguson completed the final drawings for the Air Defense Laboratory, with drawings for Building C of the group used a second time as the scaled-down complementary laboratory at the RADC in October 1952.[384] Construction was underway immediately (Plate 69). By about 1955, MIT added the Experimental SAGE building to the Air Defense Laboratory at Hanscom, with drawings likely internal rather than the responsibility of Cram & Ferguson.[385] Cram & Ferguson, like Coolidge, Shepley, Bulfinch & Abbott (Shepley, Bulfinch, Richardson & Abbott), was a prominent American architectural firm of long standing. Similar to the lineage of the Coolidge, Shepley, Bulfinch & Abbott firm, the lineage of Cram & Ferguson derived from a grandfather professional figure of the late 19th century, Ralph A. Cram (1863-1942). Cram was best known for his church architecture, practicing both in New York and Boston. Late in his career, Ralph Cram was a leading exponent of the 1920s Gothic Revival—a re-revival of an idiom dating to the mid-19th century in the United States. Cram's architectural practice went through a series of partners and names changes: Cram & Wentworth (1887-1891), Cram, Wentworth & Goodhue (1891-1897), Cram, Goodhue & Ferguson (1897-1910), and finally, Cram & Ferguson (1925-present). At the death of Frank Ferguson, Cram & Ferguson continued without name change. The firm included the four partners of Ralph Cram, Frank Cleveland, Chester Godfrey, and Alexander Hoyle. Ralph Cram was a highly philosophical architect and a prolific writer. He served as the supervising architect for Princeton University, Bryn Mawr, Mount Holyoke, and Wellesley Colleges for several decades before his retirement from active practice in 1930. The Air Force hiring of Cram & Ferguson in 1951 is somewhat of an irony—as the original firm was not affiliated with the modern architecture movement of the middle 20th century, and in fact, could be interpreted to represent its antithesis.[386] Nonetheless, by the 1951 commission for the MIT Air Defense Laboratory, the guiding principles set forth by Charles Barrett at the Cambridge Research Laboratories carried the day. Cram & Ferguson's design was generically evocative of the International Style.

As of 1956, the sets of laboratories collectively known as the Cambridge Research Center (although the MIT enterprise was officially distinct) occupied offset sites at Hanscom. In that year, a third set of R&D buildings went up for the RAND Corporation. RAND was (and remains) a think tank based in Southern California. The eight RAND buildings were aligned without regard to the precepts set forth by Mr. Barrett, yet nonetheless created a distinctive cluster. RAND erected prefabricated steel office buildings manufactured by Butler for its grouping. The think tank used the location set aside in 1951 for ancillary structures to the Coolidge, Shepley, Bulfinch & Abbott laboratories (Plate 70). By 1959-1960, when ARDC hired The Architects Collaborative for a Hanscom master plan, the Gropius collective of architects described the laboratories as

> facilities...designed in a flexible manner so that they can be used for a wide variety of general laboratory functions including office space for theoretical scientists. These facilities are characterized by the inclusion of moveable partitions and the modular distribution of laboratory services.

The Architects Collaborative individually listed the buildings comprising Shepley, Bulfinch, Richardson & Abbott's laboratory complex for electronic and geophysics research. The firm noted the specialized laboratories housed within each flexible rectangular wing. Laboratories in this

physical group included those of the propagation sciences, electromagnetic radiation physics, astrosurveillance science, communication sciences, computer and mathematical sciences, material sciences, ionospheric physics, photochemistry, atmospheric circulation, thermal radiation, operational applications, space flight physics, balloon development, aerophysics, and meteorological development. By 1960, Hanscom had added more laboratories to the east of the original laboratories of the Cambridge Research Center. These were not designed as a cohesive whole, with the exception of the four-building cluster for geophysics (Plate 71). The Architects Collaborative completed its text for the master plan with descriptions for 12 future specialized laboratories. The firm's effort brought the original collegiate planning for science laboratories at Hanscom to a logical conclusion 15 years after the idea of such cohesive research compounds had arisen.[387]

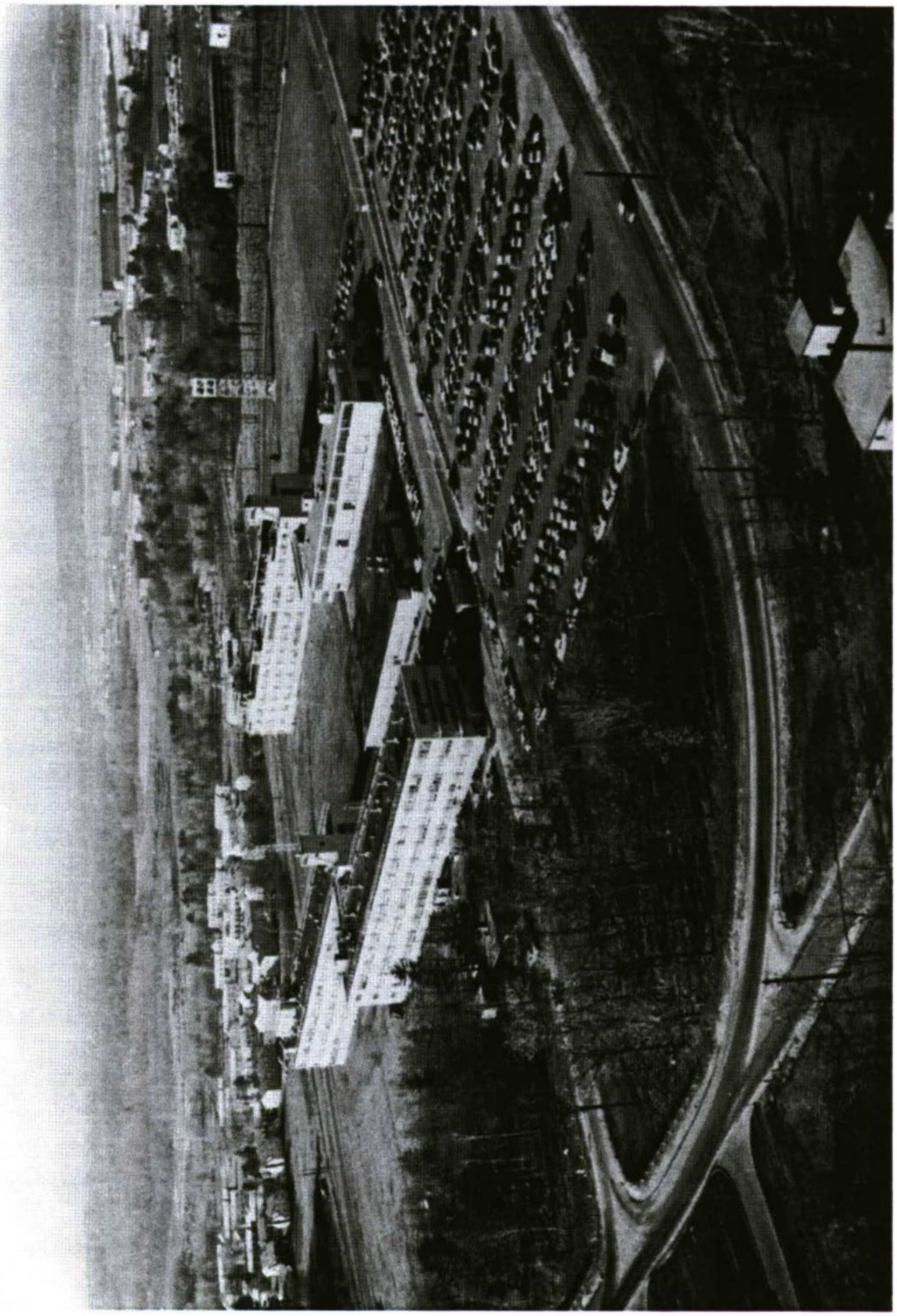

Plate 68: Shepley, Bulfinch, Richardson & Abbott. Cambridge Research Center, Hanscom Air Force Base, 1954-1956. View of the early 1960s. Courtesy of the History Office, Electronic Systems Center, Hanscom Air Force Base.

Plate 69: Cram & Ferguson. MIT Air Defense Laboratory, Hanscom Air Force Base, 1951. ADCC (Building 1301) and Experimental SAGE (Building 1302F), center (in heavy shadows) and center right. View of November 1961. Courtesy of the History Office, Electronic Systems Center, Hanscom Air Force Base.

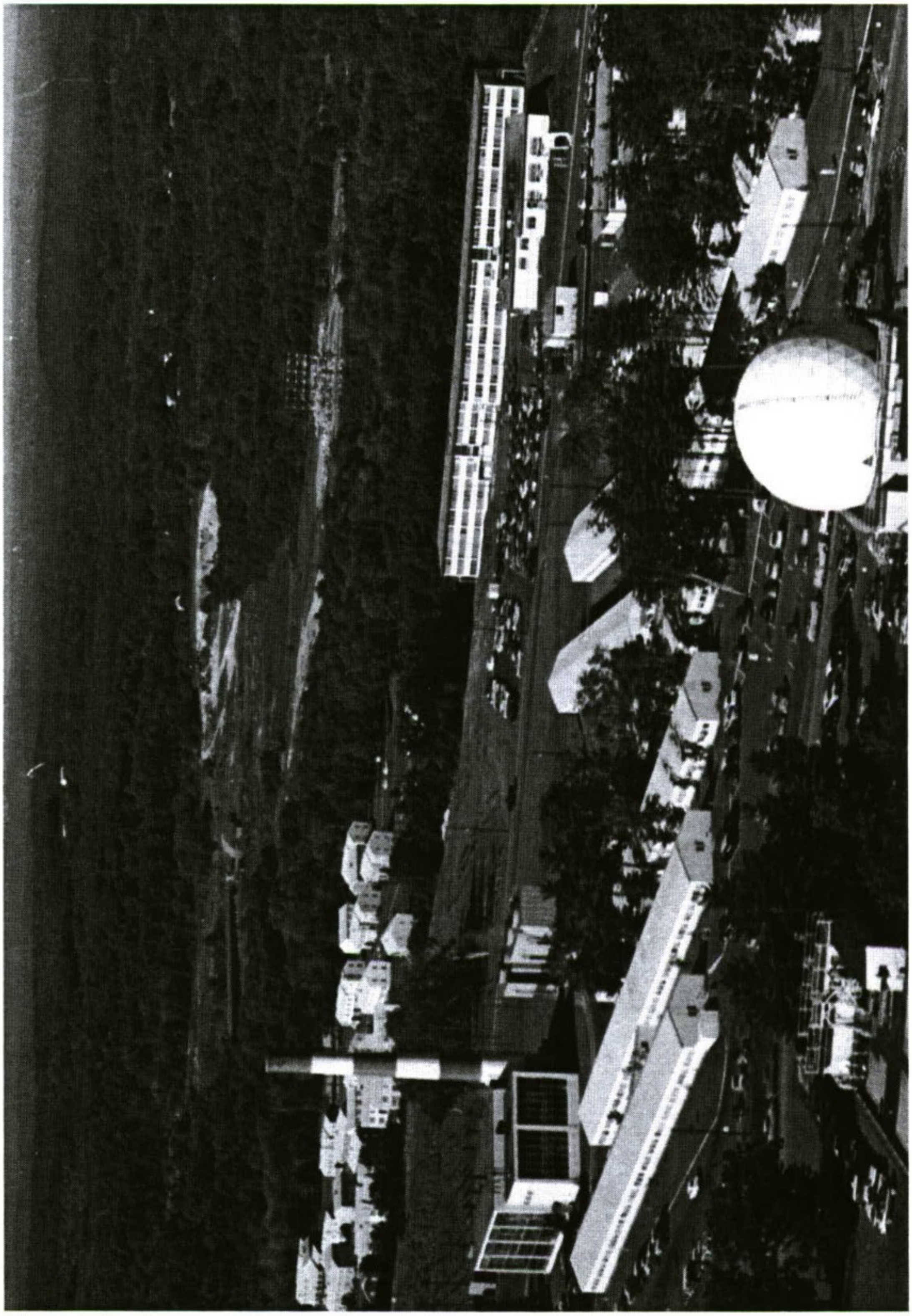

Plate 70: Butler Manufacturing, RAND R&D Complex, associated with the Lincoln Laboratory, Hanscom Air Force Base, 1956.
Courtesy of the History Office, Electronic Systems Center, Hanscom Air Force Base.

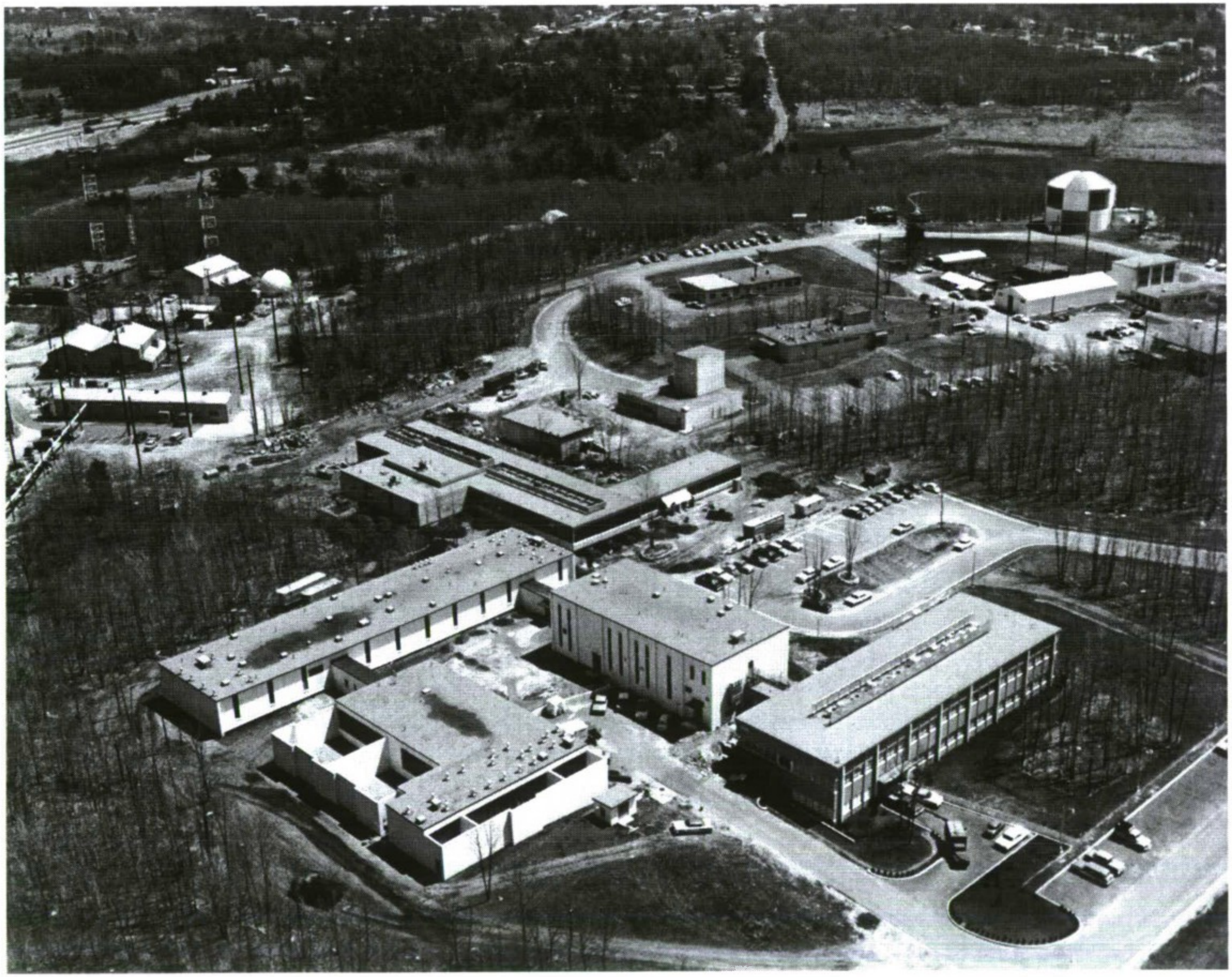

Plate 71: Geophysics Laboratories, Cambridge Research Laboratories, 1960s. Courtesy of the History Office, Electronic Systems Center, Hanscom Air Force Base.

[1] In *The Marshall Star*: "Prof. H. Oberth Will Visit MSFC for Three Days," 2, 3 (11 October 1961): 1, 7, and "Fritz Lang, Movie Director, Plans Lecture," 4, 49 (2 September 1964): 1-2.
[2] Frederick A. Alling, *History of the Air Materiel Command 1946*, volume 1 (Wright-Patterson Air Force Base: Historical Office, March 1951), 47.
[3] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego, California: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 56-77. See also, Karen J. Weitze and Joe C. Freeman, *German Village Complex, Dugway Proving Ground*, Historic American Engineering Record No. UT-35 (Plano, Texas: Geo-Marine, Inc., for Historic American Engineering Record, Rocky Mountain Regional Office, National Park Service, 1996).
[4] Benjamin H. Williams, for the Industrial College of the Armed Forces, *Research and Development*, volume 8 in *The Economics of National Security* (Washington, D.C.: Industrial College of the Armed Forces, 1954 with revisions in 1960), 97.
[5] Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944-1986* (Washington, D.C.: Office of Air Force History, 1988), 27-28.
[6] Harry P. Reiber, civilian technical representative, ATI [Air Technical Intelligence] team personnel, "ATI Target Exploitation Brief, Munich: Dinglerwerke A.G. [Aktien Gesellschaft (joint-stock company)]," 4 August 1945, with excerpt "Das Haus der Winde" from the *Munchner Illustierte Presse* of 1937, in file "Propeller Data Obtained from Germans," 4-6 August 1945, at the Air Force Historical Research Agency.
[7] Gorn, *Harnessing the Genie*, 1988, 16, 31-36.
[8] *Ibid*, 38-39.
[9] Gary R. Akin and Pamela S. Hammons (eds.), *Toward New Horizons: Science, the Key to Air Supremacy*, commemorative edition 1950-1992 (Washington, D.C.: United States Government Printing Office for the History Office, Headquarters Air Force Systems Command, 1992), xv-xvi; Gorn, *Harnessing the Genie*, 1988, 16, 19-22, 34-35.
[10] National Aeronautics and Space Administration, "Space Medicine: A Critical Factor in Manned Space Flight," published as a chapter in *Space Medicine in Project Mercury* at lsda.jsc.nasa.gov/books/mercury.
[11] Akin and Hammons (eds.), *Toward New Horizons*, 1992, xvi-xvii.
[12] "David Sarnoff Research Center," www.nasatech.com.
[13] Akin and Hammons (eds.), *Toward New Horizons*, 1992, xvii.
[14] *Ibid.*
[15] "Unique Test Building for Army Equipment," *Engineering News-Record* 131, 11 (9 September 1943): 98-100.
[16] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 88.
[17] "Mount Washington Observatory," www.mountwashington.com.
[18] Akin and Hammons (eds.), *Toward New Horizons*, 1992, xvii.
[19] *Ibid.* The Lovelace Foundation continues today as the Lovelace Respiratory Research Center in Albuquerque.
[20] Gorn, *Harnessing the Genie*, 1988, 20, 35.
[21] National Aeronautics and Space Administration, "Space Medicine: A Critical Factor in Manned Space Flight" and "Medical Aspects of Astronaut Selection and Training," published as chapters in *Space Medicine in Project Mercury* at lsda.jsc.nasa.gov/books/mercury.
[22] Gorn, *Harnessing the Genie*, 1988, 59.
[23] Dena S. Komporlides, Christopher O. Hurst, Linda Auten, Cary D. Cotterman, and Susan L. Bupp, *Historical Overview of the National Advisory Committee (NACA) and the National Aeronautics and Space Administration (NASA) at Edwards Air Force Base, California* (San Bernardino, California: Tetra Tech, Inc., for Air Force Materiel Command, February 1996), 2-21.
[24] Williams, *Research and Development*, 1954, revised in 1960, 85, 98.
[25] *Ibid*, 85.
[26] Gorn, *Harnessing the Genie*, 1988, 59-69.
[27] *Ibid*, 73-74, 77-78.
[28] Williams, *Research and Development*, 1954, revised in 1960, 103.
[29] Gorn, *Harnessing the Genie*, 1988, 87-88.
[30] *Ibid*, 1, 5-9, 88ff.
[31] While scientists and engineers existed within the American military community, and certainly within affiliated university enclaves such as the MIT Radiation Laboratories, these men are not discussed here. As

ARDC unfolded, its laboratories and test centers across the United States each featured prominent scientists and engineers. The Germans who joined them through Project Paperclip and its follow-on recruitment efforts were international colleagues. In many cases, however, the German men (and several women) arriving in the United States through Paperclip were among the very best in the world at their specialties. Germany was significantly advanced in aeronautical science, particularly in R&D toward guided missiles and space flight. Although the United States had produced engineer Robert H. Goddard, his work had not received the American professional attention it merited until after it had been furthered through German R&D of the 1920s into the early 1940s. During the first years after World War II also, the American military scientific and engineering establishment suffered from a lack of recent university graduates from which it could readily recruit and from the competition posed by private industry. Industry offered those graduates that existed, as well as the men who had worked in military laboratories during the war, higher paying jobs. The German scientists and engineers of Paperclip filled a void. Paperclippers who worked for Air Materiel Command (and subsequently, ARDC) are identified here by name and specialized expertise in all instances that the author can verify their contribution to the command. The author is attempting to clarify a significant contribution, unusual to the transitional period after World War II. Lack of equivalent naming for American scientists and engineers within the command is in no way intended to denigrate the contributions of these men and women.

[32] Harriet Buyer and Edna Jensen, *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*, Study No. 214 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, August 1948), 3-6.

[33] "Exploitation of German Specialists in Science and Technology in the United States," 6 July 1945, exhibits 16 and 17 in *Supporting Documents* for *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*.

[34] Karen J. Weitze, *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970* (El Paso: Geo-Marine, Inc., for Air Combat Command, November 1997), 161-164.

[35] "Relaxation of Certain Restrictions on 35 German PW [prisoners of war] to be Selected and Sent to Wright Field for work with German Scientists," handwritten date of 5 Nov 45 [?], exhibit 3; "German Prisoner of War Translators," 31 July 1945; exhibit 25; ""German Prisoner of War Translators," 20 September 1945, exhibit 45; and, "Use of Prisoners of War at Wright Field in Connection with OVERCAST," 13 November 1945, exhibit 70, each in *Supporting Documents* for *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*.

[36] Buyer and Jensen, *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*, 1948, 13-14.

[37] The War Department finalized the salary structure for Paperclip in German marks, with the category of "professor or doctor" that receiving the highest pay of 24,000 to 31,000 marks per annum. See *ibid*, 55.

[38] *Ibid*, 19, 26.

[39] *Ibid*, 27, 36, 40.

[40] D.L. Putt, Deputy Commanding General, Intelligence (T-2), to AiResearch Manufacturing Company, letter of 23 October 1945, first item of seven, exhibit 59, and, "James W. Tuthill, AiResearch Manufacturing Company, to Commanding General, T-2 Intelligence, Wright Field, letter of 19 September 1945, second item of seven, exhibit 59, both in *Supporting Documents* for *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*.

[41] "Exploitation of German Scientists in England," 4 November 1946, exhibit 172-A, in *Supporting Documents* for *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*.

[42] Buyer and Jensen, *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*, 1948, 42-43.

[43] Memorandum, Air Technical Service Command, Wright Field, undated, first item of two, exhibit 33, in *Supporting Documents* for *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*.

[44] Buyer and Jensen, *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*, 1948, 57-71; untitled typescript of article from the *Air Materiel Command Monthly Newsletter*, August 1946, exhibit 156 in *Supporting Documents* for *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*.

[45] Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (Cambridge, Massachusetts: Harvard University Press, 1995), 269ff.
[46] "German Scientists in the United States. Summary as of 18 June 1947," in Army Ballistic Missile Agency, *Historical Monograph Army Ordnance Satellite Program 1 November 1958.* This detailed list includes arrival dates, using agencies, assigned location, and professional specialties. In a few cases, the Army has mistranscribed arrival dates, although these are easily sorted out through internal comparisons of the dates themselves and, in some cases, acquiring agencies. (For example, 3 February 1945 is actually 3 February 1946.) Individuals not present on this list are assumed to no longer be in the United States by mid-June 1947, including Baur, Scheubel, and Sebald. See also, Note 48.
[47] Leslie E. Simon, Director of the United States Army Ballistic Research Laboratories, *German Research in World War II: An Analysis of the Conduct of Research* (New York: John Wiley & Sons, Inc., 1947), 12-24. German historians generally reference the Hermann Göring Institute as the Luftfahrtforschungsanstalt Hermann Göring (LFA), a key research establishment of the German Air Force during World War II.
[48] "Certificates of Time and Attendance Statement," 18 December 1945, items 25-27 of 33, exhibit 113, in *Supporting Documents* for *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*; and, "Review of Paperclip Summary," 4 February 1947, exhibit 33 in *Appendix* for Edna Jensen, *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, Study No. 215 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, November 1948). See also, Note 46.
[49] "Evaluation of German Scientists," 11 February 1947, exhibit 40; and "Evaluation of German Scientists," 13 February 1947, exhibit 44, both in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[50] Clarence G. Lasby, *Project Paperclip: German Scientists and the Cold War* (New York: Atheneum, 1971), *passim.* Key scientists and engineers are also discussed for their specific expertise in "Review of Paperclip Summary," 4 February 1947, exhibit 33, and, Exhibit D, attached to "Effects of Possibly Reduced Funds on Project PAPERCLIP," 1 May 1947, exhibit 105-A, both in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[51] "German Scientists in the United States. Summary as of 18 June 1947."
[52] "German Scientists and Their Dependents Assigned to Wright Field," 13 May 1947, exhibit 89, in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).* Names on the list are not always clearly typed, and the author has cross-checked each against a later list for accuracy. When a conflict exists, spellings are taken from the crisply legible "German Specialists Assigned to Wright Field 15 December 1947," typescript held in the History Office, Air Force Materiel Command, Wright-Patterson Air Force Base.
[53] A[dolf] Baeumker, *German Experience Concerning the Operation of Government Facilities by Private Companies and Non-Profit Institutions*, June 1951. In File "Facilities: Contract Op. of Govt. Facilities—Study—1951," Range 4, Area C, Row 6, Aeronautical Systems Center History Office, Wright-Patterson Air Force Base.
[54] Jensen, *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, 1948, 41-44.
[55] *Ibid*, 73.
[56] "German Scientists," 26 March 1947, exhibit 55; "German Scientists and Their Dependents Assigned to Wright Field," 13 May 1947, exhibit 89; "German Scientists," 14 November 1947, exhibit 202; and, "Income Tax Obligations for German Specialists Stationed at Rome Air Field, New York," 5 February 1948 (handwritten annotation), exhibit 238, all in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[57] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 184.
[58] Air Research and Development Command, *History of Air Research and Development Command 1 July – 31 December 1954*, 271; also, as originally compiled for Jensen, *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, 1948, 74.
[59] Jensen, *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, 1948, 72.
[60] *Ibid*, 74.

[61] "Evaluation of German Scientists," 11 February 1947, exhibit 40; and "Evaluation of German Scientists," 13 February 1947, exhibit 44, both in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[62] Dr. Hartung is discussed tied to the planning for AEDC as of May 1947. See Exhibit D, attached to "Effects of Possibly Reduced Funds on Project PAPERCLIP," 1 May 1947, exhibit 105-A, in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[63] Jensen, *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, 1948, 74-75.
[64] *Ibid*, 73.
[65] Doris A. Baker, *History of the Air Materiel Command 1948* (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, February 1951), 137.
[66] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 164.
[67] Jensen, *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, 1948, 18-19.
[68] Lasby, *Project Paperclip*, 1971, 45.
[69] "Temporary Duty Stations," 15 December 1947, 15 March 1948, and 15 June 1948, typescripts held in the History Office, Air Force Materiel Command, Wright-Patterson Air Force Base.
[70] General Engineering and Consulting Laboratory, General Electric Company, Schenectady, New York, letter to Commanding General, Air Technical Service Command, Wright Field, 1 October 1946, exhibit 11, and, "Miscellaneous Activities and Operations," 7 November 1946, exhibit 14, both in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[71] "Miscellaneous Activities and Operations," 7 November 1946, exhibit 14, in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[72] "Evaluation of German Scientists," 11 February 1947, exhibit 40, in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[73] Lasby, *Project Paperclip*, 1971, 32.
[74] "Temporary Duty Stations," 15 December 1947.
[75] "Temporary Duty Stations," 15 March 1948 and 15 April 1948, typescripts held in the History Office, Air Force Materiel Command, Wright-Patterson Air Force Base.
[76] "Temporary Duty Stations," 15 May 1948 and 15 July 1948, typescripts held in the History Office, Air Force Materiel Command, Wright-Patterson Air Force Base.
[77] "Review of Paperclip Summary," 4 February 1947, exhibit 33, and, "German Scientists and Their Dependents Assigned to Wright Field," 13 May 1947, exhibit 89, both in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists).*
[78] Baker, *History of the Air Materiel Command 1948*, 1951, 138-139.
[79] Buyer and Jensen, *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists)*, 1948, 24; Air Training Command, *Annual History School of Aviation Medicine Randolph Field, Texas, 1 July 1948 – 30 June 1949*, volume 8, 137-138.
[80] AAF Aeromedical Center, "Monthly Status Report No. 6," 31 March 1946, exhibit 132, and "Monthly Status Report No. 12," 30 September 1946, exhibit 162, both in *Supporting Documents* for *History of AAF Participation in Project Paperclip May 1945 – March 1947 (Exploitation of German Scientists).*
[81] Jensen, *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, 1948, 18.
[82] Nick Ravo, "Dr. Theodor H. Benzinger, 94, Inventor of the Ear Thermometer," *New York Times*, 30 October 1999. See also, Note 46.
[83] "Airman Survival is Aero Med's Big Job," section of the Air Research and Development Command edition, *Aviation Week* 59, 7 (17 August 1953): 392.
[84] *Ibid*, 403.
[85] "Aero Medical Equipment," subsection of Exhibit D, attached to "Effects of Possibly Reduced Funds on Project PAPERCLIP," 1 May 1947, exhibit 105-A, in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*; interview with Dr. Henning E. von Gierke by E.M. Zimmerman, 24 April 1981, transcript in File 35C 2c Studies (Paperclip /

Interviews), Box "Project Paperclip – Special Collection," History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.
[86] *History of Air Research and Development Command 1 July – 31 December 1954*, 272.
[87] "Temporary Duty Stations," 15 December 1947 and 15 July 1948. See also, Note 46.
[88] "Temporary Duty Stations," 15 March 1948; "Monthly Report on Status of German Scientists (16 Dec to 15 Jan 48 incl)," 16 January 1948, exhibit 230, in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*.
[89] Air Training Command, *History of the USAF Aerospace Medical Center 1 January – 31 October 1961*, volume 3, 14, 105-106; Edward B. Alcott, *Aerospace Medical Division: Twenty-Five Years of Excellence 1961-1986* (Brooks Air Force Base: History Office, Aerospace Medical Division, 1986), 30. An example of an early Haber and Haber article in the *Journal of Aviation Medicine* is "Possible Methods of Producing the Gravity-Free State for Medical Research," 21, 5 (October 1950): 395-400.
[90] Ford Burkhart, "Fritz Haber, Dies; Simulated Weightlessness of Space," *New York Times*, 29 August 1999.
[91] Air Training Command: *United States Air Force School of Aviation Medicine History 1 July 1947 – 30 June 1948*, volume 7, and, *Annual History School of Aviation Medicine Randolph Field, Texas, 1 July 1948 – 30 June 1949*, volume 8, *passim*. See also, Note 46.
[92] *United States Air Force School of Aviation Medicine History 1 July 1947 – 30 June 1948*, volume 7, *passim*.
[93] "Monthly Report on German Nationals," School of Aviation Medicine, Randolph Field, Texas, 1 April 1947, exhibit 191-B, in *Appendix* for *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*; Surgeon General, United States Air Force, *German Aviation Medicine World War II* (Washington, D.C.: Government Printing Office, April 1950), iii-iv, *passim*.
[94] In the *Journal of Aviation Medicine*: Heinrich W. Rose and Ingeborg Schmidt, "Factors Affecting Dark Adaptation," 18, 3 (June 1947): 218-230, 243; and, S.J. Gerathewohl, "Method for the Analysis of Psychomotor Performance Under Hypoxia," 22, 3 (June 1951): 196-206.
[95] *History of Air Research and Development Command 1 July – 31 December 1954*, 277-278.
[96] Air Research and Development Command, *History of Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 3, 50.
[97] Air Technical Intelligence Center, *History of Air Technical Intelligence Center 1 January – 30 June 1952*, 33.
[98] *History of Air Research and Development Command 1 July – 31 December 1954*, 263, 277.
[99] *History of Air Technical Intelligence Center 1 January – 30 June 1952*, 35-36.
[100] Air Technical Intelligence Center, *History of Air Technical Intelligence Center 1 July – 31 December 1952*, volume 6, 31-32.
[101] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 167-168.
[102] Helen Brents Joiner, *History of the Army Ballistic Missile Agency February – June 1956*, 78.
[103] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 168-169; *History of Air Research and Development Command 1 July – 31 December 1954*, 280-291.
[104] *History of Air Research and Development Command 1 July – 31 December 1954*, 292-299a.
[105] *Ibid*, 299.
[106] "Assignment of Doctors Lettau, Penndorf, and Diem to Atmospheric Laboratory," memorandum from Milton Greenberg, Atmospheric Research and Development Planning Engineer to Colonel Duffy, 11 September 1947, in Paperclip File held in the History Office, Electronic Systems Center, Hanscom Air Force Base.
[107] "German Specialists Assigned to Wright-Patterson AF Base," 15 May 1948.
[108] Dr. Ruth Liebowitz, hand-written notes on the Paperclippers assigned to the Cambridge Research Laboratories (Center). Notes from a telephone conversation with Milton Greenberg of 13 November 1986 indicate that Mr. Greenberg, a recruiter of German scientists for Cambridge, stated that Dr. Diem was at Cambridge very briefly. In Paperclip File, History Office, Electronic Systems Center.
[109] Evelyn D. Sullivan, *Historical Data Cambridge Field Station, 3160th Electronics Station, 1 January – 30 June 1949*, volume 9, 167.
[110] Thomas W. Thompson, "Rome Laboratory: A Brief History," www.if.afrl.af.mil.
[111] "Putting Avionics Research to Work," *Aviation Week*, 17 August 1953, 238, 240.
[112] Irving Stone, "Cambridge's Bailiwick: Earth, Sky, Sea," *ibid*, 244.
[113] "Dr. Kuettner Will Manage Saturn –Apollo at MSFC [Marshall Space Flight Center]," *The Marshall Star* 2, 15 (10 January 1961): 3.
[114] Sullivan, *Historical Data Cambridge Field Station, 3160th Electronics Station, 1 January – 30 June 1949*, volume 9, 76, 126-128, 131, 164-167.

[115] "Dr. Kuettner Will Manage Saturn," *The Marshall Star*, 10 January 1961; "Kuettner Pictured in LIFE Article," *The Marshall Star* 1, 2 (5 October 1960): 7.
[116] "Specialists on Order from EUCOM [European Command]" and "Requested But Not Ordered," lists of 18 June 1947 in *Historical Monograph Army Ordnance Satellite Program 1 November 1958.*
[117] Lasby, *Project Paperclip*, 1971, 32, 251-252.
[118] Simon, *German Research in World War II*, 1947, 76.
[119] Liebowitz, hand-written notes on the Paperclippers assigned to the Cambridge Research Laboratories (Center).
[120] William H. Honan, "Martin Schilling, Developer of V-2 Missile, Dies at 88," *New York Times*, 8 May 2000.
[121] Karen J. Weitze, *PAVE PAWS Beale Air Force Base: Historic Evaluation and Context* (Sacramento: KEA Environmental, Inc., for Air Combat Command, February 1999), 35-37.
[122] Lasby, *Project Paperclip*, 1971, 3-5.
[123] Dr. Eli Brookner, Raytheon, discussions with Karen J. Weitze, at Hanscom Air Force Base, 9 March 2001.
[124] Lasby, *Project Paperclip*, 1971, 4.
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Part IV: Major Tenant Missions at Installations across the Command

Beyond their primary role in research, development, testing, and evaluation, many of today's Air Force Materiel Command (AFMC) installations also hosted tenant missions during the Cold War. In the four examples discussed here, tenant missions were of such breadth and depth that they appeared at multiple bases. These missions represented vital Cold War programs of lengthy duration, with infrastructure built to support them throughout the United States and overseas. For two of the four examples, the tenant mission partially derived from research and development (R&D) conducted by Air Materiel Command and its follow-on commands Air Research and Development Command (ARDC) and Air Force Systems Command (AFSC). With a few exceptions, installations serving the research side of today's command were those that historically hosted large-scale tenant missions, although several logistics depots also participated where physical location made the particular mission important. Considered across AFMC are the tenant missions of fighter air defense, strategic bomber alert, long-range early warning radar, and space flight. The air defense mission was particularly complex and required an integrated network of radars, alternate information sources, squadrons of fighter aircraft on alert, weapons systems, and command posts. Air Force commands associated with the tenant missions discussed below were those of Air Defense Command (later, with a name change to Aerospace Defense Command [both, ADC]), Tactical Air Command (TAC), and Strategic Air Command (SAC). The National Aeronautics and Space Administration (NASA) also sustained tenant activities at several AFMC bases. With organizational changes at the end of the Cold War, Air Combat Command (ACC) assumed continuing TAC and SAC missions, while Air Force Space Command (AFSPC) inherited selected ADC missions not passed to TAC and SAC at an earlier date.

Air Defense of the Continental United States

ADC, and subsequently TAC, organized and managed the immediate perimeter air defense of the continental United States. ADC's efforts continued a program initiated during the last years of World War II. The air defense mission featured elaborate, multiple generations of command and control centers (command posts) with technologies represented in five distinct time periods with representative infrastructure: 1942-1945, 1948-1958, 1958-1963, 1963-1982, and 1982-present. Buildings and equipment for these command posts were different for each stage of the program, with the most well-known the Semi-Automatic Ground Environment (SAGE) of 1956-1963. Predictably, these layers of command and control overlapped with one system still operating as another came on line, and with adaptation of preexisting centers for later use. The command posts had an associated lexicon of names that were particular to their periods. The nomenclature consistently derived from the labeling for the system developed in World War II. Most common were "control centers," "direction centers," "combat centers," and sometimes just "command posts." During the earliest years, the centers received information from radar stations, a separate web of physical locations also physically updated over time, as well as from ground observers. Radars and observers channeled the information to a smaller group of true command posts that assessed the information and scrambled squadrons of alert fighter aircraft. Each center managed a discrete geographic area very similar to the depot program of Air Materiel Areas (AMAs). Fighter-interceptor squadrons (FIS) formed yet another network of locations at Air Force installations throughout the United States. Infrastructure for alert configurations of FIS varied, dependent on when, and for what duration, a location sustained alert. Ancillary structures included alert hangars, maintenance hangars, ready shelters, ready dormitories, operations buildings, training structures, weapons support, and munitions compounds. FIS alert also featured distinctive aprons and taxiways at host installations. The overall program lasted throughout the Cold War from 1945 to 1991. Actual air jurisdictions changed geographic boundaries many times. The number of command posts and FIS locations grew, shrank, and shifted

in a fluid dynamic throughout the war. Generally radar stations upgraded their equipment on their original sites, or went off line without replacement at a new location.

Command Post Networks

Lineage from World War II through the Cold War

The Air Force system of air defense for its continental borders at the beginning of the Cold War derived directly from that of the British Royal Air Force (RAF). In a limited way during 1944 and 1945, the American Army adapted the methods and infrastructure developed by the RAF. The RAF had established the principle of an "Aircraft Fighting Zone" as early as 1923, with each zone patrolled by assigned fighter aircraft squadrons and additionally protected by manned antiaircraft gun emplacements. During war, the RAF system called for an "Observer Corps" to man a network of posts every five miles (or coverage of about one county) and to telephone information on any foreign aircraft to their "group centers." From these centers, personnel further analyzed the received intelligence, phoning it to a "Fighter Area Headquarters" and to neighboring group centers. The first-tier centers focused on "operations rooms" that were planned and developed through experiences gained during air exercises. "Their main feature was a plotting room containing a large map-table." From its initial use, the map table (or, plotting board) was in continuous upgrade. Those who tracked aircraft devised specifically colored counters and coordinated them with five-minute segments of the operations room clock. Other individuals recorded information on aircraft readiness, performance notes, and weather conditions on vertical chalkboards. Men in the group centers and at the Fighter Area Headquarters plotted and evaluated continuous layers of information, with telephone connections to each other and to antiaircraft batteries and searchlight stations. A primitive, single-channel radio-telephone link served as the communications device between group centers and fighter aircraft in the air. The RAF refined its programmatic framework for manned air defense zones during the later 1920s and 1930s, constructing a network of tentative infrastructure before the outbreak of World War II.[1]

Deeply concerned about the rise of German air power and the increasing probability of bombing raids on England, the RAF moved to strengthen and improve its air defense system in 1934 following poor performance of its units during the annual mid-year air exercise. During 1935 and into spring 1937, service trials for the new device of radar greatly improved the reported accuracy of bomber positions and allowed men in the sector operations rooms to direct fighter aircraft to target interception with an equivalently improved precision.[2] Up through the end of 1937, all RAF efforts toward an effective air defense system had been practice for the actual conditions of war. In order to improve the equipment and techniques used in the operations rooms of the group centers, as well as those in the Fighter Area Headquarters, aircraft taking the role of the enemy had transmitted signals or flown prearranged courses to facilitate their own tracking. Radar equipment could track accurately within an angle of 120 degrees in azimuth, to a distance of 30 miles (80 miles much less accurately) above altitudes of 8,000 feet. Radar accuracy deteriorated below that height and became completely unreliable under 5,000 feet. To adjust for the parameters of early radar, the RAF decided to place equipment close enough together along the British coast so that two radar stations covered every sector. After analysis, personnel could pass on the best information to their counterparts in the operations rooms of the group centers for plotting on the map boards. The gleaning process, described as "filtering," led to the requirement for another layer in the evolving air defense infrastructure: filter centers. The very first operational filter center was an experimental one of July 1937, installed at Bawdsey and coordinated with the headquarters for the sector at Biggin Hill. The first filter centers imitated the operations rooms of group centers, with key features such as a map table and its counters. Within the next months, improvements to the network continued with practice tracking of civilian airliners between Europe and England.[3] Filter centers would also become a vital

part of the American air defense network in late World War II and again during the early years of the Cold War.

The first large-scale test of the British system, the Home Defence Exercise, occurred in August 1938, and led directly to numerous improvements in RAF air defense. By this date, the impending war with Germany was a strong impetus. The permanent air defense network required the installation of special telephone lines between centers, as well as the design and construction of an underground facility for Headquarters Fighter Command. By spring 1939, the British intention was to place each level of command and control underground, from Headquarters Fighter Command to the sector level. The RAF considered the layouts used in the interiors of the various command posts to be experimental, and thus delayed the erection of permanent quarters below ground—which once in place could not be modified further. By March 1939, only one underground command center was functional at Bentley Priory (for Headquarters Fighter Command), but its hastily constructed concrete structure retained dampness and made the delicate equipment within it unreliable.[4] At this same time, 12 of 19 planned radar stations were on line. Telephone and teleprinter lines remained incomplete.[5] With the entry of England into World War II in September 1939, the RAF air defense system became formally operational with Fighter Command actively engaged in intercepting enemy aircraft. The RAF continued to erect radar stations and levels of information available increased. Individuals manning the entire system, from radar stations to filter centers, were amateur volunteers. The accuracy of the collected information and its transference was erratic. By June 1940, the RAF provided 15 trained filterers with backgrounds in science and math for the effort, and as the war progressed the Women's Auxiliary Air Force successively took over the majority of the filter and operations room duties. As of early March 1940, the command post facilities for Headquarters Fighter Command were operational in their underground structure.[6]

The year 1940 was pivotal for the emergence of air defense in England, and for its first consideration in the United States. The Battle of Britain, between July and October, became the test for which the RAF had planned its air defense system. German aircraft outnumbered those of the RAF. The radar early warning network, coupled with what was known as the "fighter control system," made the difference between success and failure. The Germans perceived the British fighter force as substantially larger than it actually was and misconstrued its method of operations. The RAF learned numerous lessons for continuing the improvement of the nascent air defense system, including the development of alternate group centers at the sector level to serve as backup should facilities be damaged during attacks.[7] Only the headquarters for Fighter Command was underground by this date. As anticipated, it was the aboveground structures that were vulnerable to being knocked out. In the United States, the Army set up a new command, ADC, with its headquarters established at Mitchel Field on Long Island, New York. Soon under discussion were "information" and "filter" centers, with a test sector exercise run in northern New York using the Watertown National Guard Armory as a combined information and filter center for First Army war games. ADC had two affiliated Signal Corps units, and the SCR (Signal Corps Radio)-270 and SCR-271 search radars offered the earliest detection and warning devices appropriate to the air defense mission. ADC personnel used a simple, horizontal plotting board in its command post at Watertown in August 1940. At the close of the Battle of Britain in September 1940, the British elected to share information on their developed air defense system with the United States. The following month, two American Army officers flew to England to study the RAF Fighter Command's methods, equipment, and infrastructure for air defense.[8]

As of 1941, ADC began to plan for an air defense network in the United States. The command established an experimental air defense sector in the Northeast and set up two temporary information centers: one in the National Guard Armory in Boston for the northern part of the physical jurisdiction and a second in the Bell Telephone Company building in New York for the southern section. ADC

hired Skidmore, Owings & Merrill of New York to design its New York Information Center in the space leased from Bell Telephone, using this facility as the prototype for future Information Centers.[9] In order to winnow out poor information, ADC soon took the same path that the British had followed. The command established an intermediate Filter Center between its volunteer ground observers and the Information Center. Tests using the Boston and New York Information Centers led to the delineation of four Air Districts in the Northeast, Northwest, Southeast, and Southwest as of early 1941 (Plate 72). By March 1941, the four numbered Air Forces replaced the four Air Districts, and these each received equivalently numbered Interceptor Commands. The Interceptor Command jurisdiction was I in the Northeast, II in the Northwest (Washington and Oregon), III in the Southeast, and IV in the Southwest. However, ADC was primarily a test organization, subject to the vagaries of such agencies. The Army inactivated ADC in June 1941, reassigning its staff to I Interceptor Command with the First Air Force at Mitchel Field.[10] I Interceptor Command continued to set up a network of Information and Filter Centers for its jurisdiction. Next, the command added centers along the entire East Coast, from north to south. I Interceptor Command staffed the centers with civilian volunteers for practice air defense maneuvers by the Signal Corps in October. Thereafter, the command maintained the skeletal air defense organization for future need. The other Interceptor Commands also continued to operate at a minimal level, with IV Interceptor Command adding Information Centers in San Francisco, Los Angeles, Seattle, Portland, and San Diego (the latter, a Filter Center serving as a subinstallation to Los Angeles).[11] Everything changed again with the Japanese bombing of Pearl Harbor, Hawaii, and the entry of the United States into World War II. As of 8 December 1941, I Interceptor Command recalled its Information Center volunteers in Boston, New York, Philadelphia, Albany, and Norfolk, as well as the volunteers for Filter Centers in Harrisburg and Baltimore.[12] An equivalent situation unfolded on the West Coast.

The day after the bombing of Pearl Harbor marked the beginning of American efforts toward an air defense infrastructure that would directly underlay the system required during the Cold War. First authorization was for 20 Information and Filter Centers, with the needed American Telephone and Telegraph Company equipment available only for eight. As of 1942, I Interceptor Command designated the air defense areas set up in the Northeast as Fighter Control Areas, changing its name to I Fighter Command. The Army expanded the network under the command to 10 Information Centers and 16 Filter Centers by autumn. The layered network of information and assessment posts grew to include Filter Centers, Information Centers, and Fighter Control Centers. Within its umbrella organization, the Aircraft Warning Service (AWS), the network fed from bottom to top. The Women's Auxiliary Army Corps (WAAC) staffed Information and Filter Centers, replacing female civilian volunteers. The Army also decided upon the creation of alternate Information and Filter Centers, with definite plans made in late 1942. Again the American telephone companies played a primary role in this very first air defense system, with the New York, New England, and Bell Telephone Companies all retaining ownership of the alternate centers. The telephone companies also directly maintained these facilities.[13] In all cases, the AWS built Filter and Information Centers within existing structures, often in the basements of office buildings. Command post decisions occurred in the Information Centers. Leases for the space were annual, with the Air Defense Board raising the question of a permanent infrastructure as of summer 1942. The greatest amount of air defense activity occurred within I Fighter Command during this period, with the command moving its centers fairly often during these first months—making permanent construction as yet impractical. The AWS deemed Skidmore, Owings & Merrill, later known for its cutting-edge International Style designs and going by the name SOM, the only architectural firm "thoroughly familiar with and experienced in designing and installing Information and Filter Centers." SOM handled the renovations and interior design work for the first centers. The firm also completed the drawings for the permanent Fighter Control Center to come.[14]

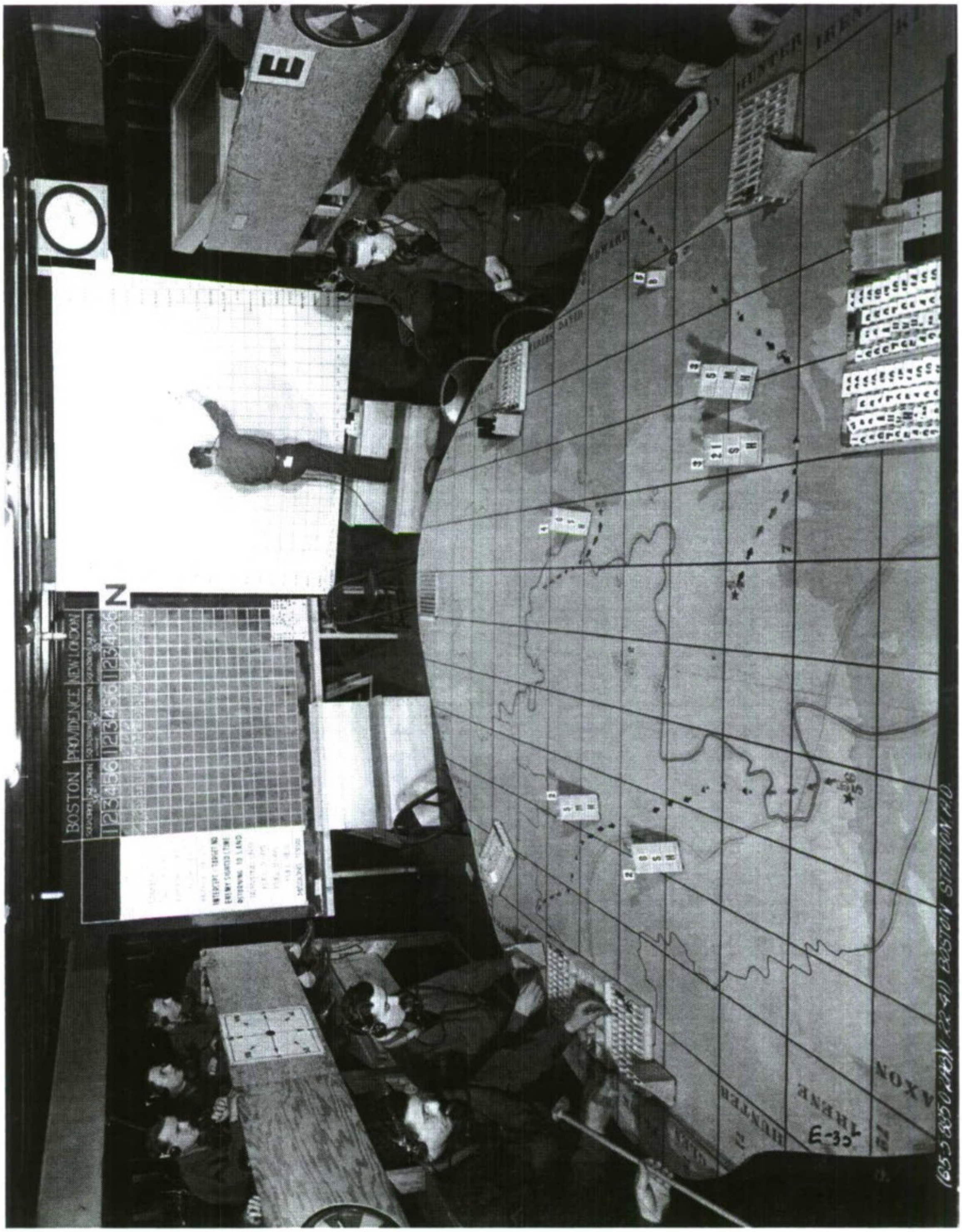

Plate 72: Information Center, Boston, January 1941. In *History of the I Fighter Command Part III December 1941 – July 1944*, volume 3.

Key improvements occurred to the evolving air defense network in 1943, with permanent infrastructure under construction. As of mid-June, the War Department adopted the World Wide Grid System. The grid mapped the world through a system of latitude and longitude lines. An overlay divided geography into lettered sections and subsections. The uniform mapping device necessitated new filter and operations plotting boards. This was the first major revision for such boards in a long line of innovation to come.[15] The Army began to analyze the fine points of efficiency and accuracy in reporting possible enemy aircraft: plotters and filterers were seated opposite each other across the board, with other personnel seated above them in a balcony. Designers replaced the pulse clocks to better coordinate them with the job of the plotters.[16] These were precisely the kinds of tasks undertaken on a continuous basis by the Watson Laboratories during 1946-1950, and by the Rome Air Development Center (RADC) at Griffiss Air Force Base throughout the Cold War thereafter. The previous summer of 1942 had also witnessed the first efforts to locate appropriate sites for Very High Frequency (VHF) radar and communications equipment to feed more accurate information to analysts at the AWS centers. By October 1943, however, the War Department saw an air threat to the continental United States as unrealistic and all available men were needed overseas. Operations at Filter and Information Centers sharply fell off. The Army completely terminated those in the Southeast by late February 1944.[17] Simultaneously with the process of gearing up and scaling back, the AWS submitted its plans for Fighter Control Centers.

The Fighter Control Center project dated to July 1942. I Fighter Command oversaw SOM's designwork for the Center, with standardized drawings shipped from the Northeast to the other Fighter Commands. At this stage, the functions of gathering information (through volunteer ground observers), sorting it (in Filter Centers), and passing it to a centralized location for military command actions (the Information Centers) shifted somewhat. Filter Centers temporarily ceased to be a part of the layering, with Ground Observer Posts (civilian volunteers) planned to report directly to Information Centers. Reports then were to go from the Information Centers to the Fighter Control Centers (also described as Operations Blocks), where AWS personnel would direct interceptions from the Operations Room (war room).[18] As of early 1944, the skeletal system that would dominate the Cold War had emerged. Information Centers would become Air Defense Direction Centers (ADCCs) and then SAGE Direction Centers. Fighter Control Centers would evolve into Air Defense Control Centers (ADCCs) and then SAGE Combat Centers.

As built, the Fighter Control Center program was fragmented in both physical form and in mission, but it laid the fundamental groundwork for the Cold War air defense network of the 1950s-1980s. With the pull-back of the Filter and Information Centers program, a parallel recommendation requested the curtailment of construction for the Fighter Control Centers. While this did lower the number of Fighter Control Centers completed, the program went forward on both the East and West Coasts under I and IV Fighter Commands. After the United States formally entered World War II in December 1941, and efforts toward a renewed air defense system were underway in 1942, the Army shuffled the four air defense jurisdictions previously established as Interceptor Commands to become I Fighter Command, III Fighter Command, IV Fighter Command, and Central Defense Command.[19] IV Fighter Command absorbed the previous Washington and Oregon jurisdiction of II Interceptor Command of the pre-war period, with the new Fighter Commands covering the borders of the United States considered most vulnerable. Central Defense Command was responsible for a much less threatened interior. The Army designated its air defense network as the VHF Control Systems Project in mid-1942 and extended it to the three Fighter Commands. The Army planned Fighter Control Centers and ancillary installations for all jurisdictions. I Fighter Command sustained its territory along the East Coast to Florida. III Fighter Command controlled the coastal region from the west coast of Florida along the Gulf Coast to El Paso. IV Fighter Command managed the western United States from the coastline inwards to the Rocky Mountains. Not surprisingly, the VHF Control Systems Project grew out of an earlier "fortress defense" plan of Western Defense Command, the

Fourth Air Force, and IV Fighter Command.[20] The West was the first coast threatened, after the bombing of Pearl Harbor, although attentions quickly turned to the East with the largest Fighter Control Center planned for that region.

By August 1942, IV Fighter Command was actively discussing the VHF Control Systems Project. The first stage involved testing sites for their appropriateness to house equipment—whether or not sites offered sufficient lack of obstruction for radar to operate optimally. IV Fighter Command planned for six Fighter Control Centers at Paine Field (north of Seattle); in the vicinity of Aberdeen, Washington (becoming Olympia); on Grizzley Peak east of Berkeley, California; in the vicinity of Mount Lee in Los Angeles (a location which became Lookout Mountain in North Hollywood by 1943); in the Palos Verdes Hills, south of Los Angeles; and, on Mount Soledad near San Diego.[21] As 1943 unfolded, the six centers grew to seven, with a location also planned near Portland, Oregon. Construction in the West was underway by late spring and paralleled that in the Northeast for I Fighter Command. By July 1943, construction for the Fighter Control Centers was at various stages of completion: just initiated for the Center at Paine Field; one-third complete for Grizzley Peak in Berkeley; just beginning for the North Hollywood site; 37% complete for the Palos Verdes site; and, completed through basement excavation for Mount Soledad. The Fighter Control Centers planned for Olympia and Portland were on hold.[22] The plans internal to IV Fighter Command, as would be true for I Fighter Command, started as more elaborate than was practical during the war. Also similar was a fluidity in site selection, with changes of center locations. Information and Filter Centers preceded planning for Fighter Control Centers. As of June 1944, the Army pulled back its operation of Fighter Control Centers in the West, simultaneous with similar actions in the East (see below). IV Fighter Command returned equipment not needed for Western air defense training locations to Air Service Command at Patterson Field.[23]

IV Fighter Command kept three of its Fighter Control Centers for air defense training purposes, renaming them Region Control Centers. The centers continued were at Paine Field (north of Seattle), Grizzley Peak (Berkeley), and Lookout Mountain (North Hollywood). As a part of the new "Region Control Center" concept, IV Fighter Command also planned to keep the Fighter Control Center built in the Palos Verdes Hills and on Mount Soledad in San Diego. These two facilities were to be incorporated under the jurisdiction of the Region Control Center in North Hollywood. (In 1947, the Lookout Mountain site hosted Lookout Mountain Laboratory, a classified film studio responsible for the production of motion pictures and still photographs for the Department of Defense and the Atomic Energy Commission (AEC)—that is, for the filming of atomic and thermonuclear tests in the Marshall Islands and at the Nevada Test Site. The laboratory operated under the command of the Air Force until its deactivation in 1969.)[24] The Fourth Air Force, continuing training exercises and responding to potential threats from Japan, established three parallel Air Defense Regions. A Region Control Center managed each, with subordinate Area Control Centers.[25] The Fourth Air Force particularly guarded against threats from Japanese balloons. During late 1944 until September 1945, the Fourth Air Force developed sequential air defense plans, with provisional air defense wings to be mobilized during emergencies. The Region Control Centers coordinated alert fighter and bomber aircraft, as well as antiaircraft artillery units.[26] The air defense network set up for the West Coast went furthest toward an integrated system of command and control, alert aircraft, and integrated weapons response that would shortly characterize the air defense network of the Cold War.

The development of an air defense network for I Fighter Command in the Northeast directly paralleled efforts of IV Fighter Command in the West. For I Fighter Command, the $2.2 million VHF Control Systems Project included plans for nine Fighter Control Centers (at $150,000 each for new construction) as of December 1942.[27] The Fighter Control Centers were to manage nine air defense areas from Maine to Virginia. Construction for the eastern Fighter Control Centers was underway as of May 1943. Records imply that the renovation of existing buildings replaced new

construction at selected government reservations.[28] Information and Filter Centers began deactivating before the Army could activate any Fighter Control Centers in the East, catching the full system at cross purposes. I Fighter Command then turned to training for air defense. As of July 1944, the command maintained Fighter Control Centers at Roslyn, New York, near Mitchel Field; Andrews Field outside Washington, D.C.; and, Langley Field in Virginia.[29] As of May 1943, the Army had reduced its nine Fighter Control Centers for I Fighter Command to seven, with the two planned for Portland and Bangor, Maine, cancelled completely. By late November 1943, the Army also stopped plans for Fighter Control Centers near Falmouth, Massachusetts, and Windsor Locks, Connecticut.

There were five Fighter Control Centers under the final "streamlined" plan, with each in place by 1 January 1944, at: Bedford Field (the future Hanscom Air Force Base); Roslyn, near Mitchel Field; Fort Dix, New Jersey; Andrews Field in Maryland; and, Langley Field in Virginia. The Army planned new construction for the Fighter Control Centers at Roslyn and Fort Dix.[30] Air Service Command at Patterson Field had the responsibility to develop and provide the equipment for the Fighter Control Centers, which initially included five SCS (Signal Corps [fighter control] System)-2 installations to accommodate a decentralized VHF network for two-way radio communication. The Signal Sections of Air Service Command at the Rome and Middletown Air Depots installed the needed equipment components for the SCS-2 setups. The relationship between I Fighter Command and Air Service Command foreshadowed the early Cold War relationship between Continental Air Command (CONAC) and Air Materiel Command of the late 1940s, when development of infrastructure and equipment for air defense moved to the next level. During the spring of 1944, the Army Air Forces further consolidated its plans for a network of Fighter Control Centers in the Northeast, reducing the five of January to three in June. The Army dismantled facilities at the two centers removed from the program, Bedford Field and Fort Dix.[31] The three Fighter Control Centers at Roslyn, Langley, and Andrews made it to operational status on 23, 24, and 30 June 1944, respectively.[32] At these locations I Fighter Command collocated Fighter Control Centers with transmitters and receivers. The Army coded Fighter Control Centers as "Z" installations; transmitters as "U" installations; and, receivers as "R" installations. The full VHF Control Systems Project included direction-finding homers ("H" installations), direction-finding fixers ("K"), relay stations ("M"), and emergency Fighter Control Centers ("W") (presumably unbuilt).[33]

After World War II, CONAC and Air Materiel Command continued to work on the development of a comprehensive system of command and control centers for an air defense network to operate throughout the United States. The establishment of the network involved very basic R&D for proto-hardened (protective) construction for the tiered centers, as well as improved radar, communications, assessment, and computer equipment. Air Materiel Command at Wright Field was immediately involved through specialized efforts at the Watson Laboratories, the Cambridge Field Station in Boston (and subsequently, the Cambridge Research Laboratories / Center at Hanscom), and the RADC. As of October 1948, the Air Installations Division of Air Materiel Command developed the technical specifications for a system of command and control buildings. During early 1949, the architectural-engineering contract for the air defense network went to the Chicago firm of Holabird, Root & Burgee. As of October, the firm completed drawings for what CONAC, and subsequently a reactivated ADC, termed ADCCs and ADDCs. (See the fuller discussion in Part III, under Special Missions, Sophisticated Civil Engineering.)

The command and control buildings were a high priority project for ADC, with efforts taken to obscure the function of the network should the drawings fall into enemy hands. Before Holabird, Root & Burgee finalized the drawings, the Air Force required the firm to remove all references to an air defense mission and retitled the command posts as Operations Buildings, Types 1, 2, 3, and 4. The command posts could function as alternates for one another. At first this situation was due to

their very similar design and engineering, but after the system was completed the adaptability became formal.

> The regulation published on 11 March 1953 which directed each ADDC to function as an ADCC within their own subsectors whenever communications were broken between them and the ADCC...appeared to be the best that could be drawn up under the circumstances.[34]

The Air Force named this first Cold War air defense network the Aircraft Control & Warning (AC&W) system, paralleling the ASW of World War II. The names, layering, and alternate functions of the four Operations Buildings was complex and confusing. ADC alternately called the Operations Building Type 1 an Early Warning Station (EWS). ADC appears to have constructed the Type 1 building for radar stations serving as early warning and for those functioning as Ground Control Intercept (GCI) units. In both cases, the Type 1 building was a radar Direction Center, and as such could take over for the Direction Centers layered above it in the network. ADC directly labeled the Operations Buildings Type 2 and 3 as Direction Centers, with one planned as an "Air Direction Center – Heavy" (ADC-H) and one as an "Air Direction Center – Light" (ADC-L). The Direction Center designation for the Type 2 and 3 Operations Buildings is somewhat deceptive. The Type 2 building replaced the Information Center of World War II and served as a true Direction Center at selected AC&W radar stations. The Type 3 Operations Building typically accompanied the Type 4 building on ADCC sites as an administrative structure, rather than as a primary command post. As built, the Type 3 Operations Building was the only one of the four structures that was not protective construction (see Plate 82). Distinctions between the radar stations, all manned as AC&W posts, were generally in the type of radar used at the site, with the AN/FPS-3 radar typically at the first early warning and GCI sites and the AN/CPS-6 at ADDCs. The Type 4 Operations Building was the final layer of command post in the system, serving as the Control Center. The ADCC replaced the Fighter Control Center of 1942-1944. Holabird, Root & Burgee designed and engineered the Type 1, 2, and 4 Operations Buildings to be both traditionally bomb- and gas-proof, as well as resistant to the perceived new Cold War threats of atomic and biochemical warfare (see Plates 54-58). At the outset of the 1950s, experimental ADCCs and ADDCs were the responsibility of the Cambridge Research Laboratories (Center) and the RADC (see Volume II, Chapters 5 and 11).

While Air Materiel Command undertook preliminary R&D toward an infrastructure for air defense, the Army Air Forces (subsequently, the Air Force) set up a tentative command structure for the mission. Immediately following the end of World War II, the Army shifted air defense responsibility to its reserve corps, the National Guard. The establishment of an Air National Guard (ANG) led to conflicts between the older National Guard Bureau and the new Guard arm, with virtually everything associated with air defense in conflict. In 1946, the joint American-Canadian Military Co-operation Committee printed its *Air Warning and Air Interceptor Appendix* calling for an air defense network of command posts and radars across the North American continent. The Army Air Forces first intended that ANG field 84 radar stations to serve as early warning for 36 American cities. Radar stations would in turn feed information to 24 direction centers, which would continue to channel air intelligence to 12 control centers located at a National Guard Wing Headquarters. As envisioned by the Army Air Forces and the National Guard Bureau, the ANG network—already called an Aircraft Control & Warning network and employing the terminology of Air Force air defense—foreshadowed ADC's *Plan Supremacy* of 1947.[35] Stimulated by the Communist coup in Czechoslovakia and the Berlin blockade in 1948, ADC announced a more detailed air defense program calling for 85 AC&W radar stations and 11 command and control centers. Plans for this network moved forward with the disbanding of ADC the same year and the assumption of the air defense mission for a period within CONAC.[36]

The AC&W program for 85 radar stations and 11 command and control centers was under construction as of late 1949. In the beginning, a strong tie back to the Fighter Control Centers of World War II characterized the program. For selected cases, the air defense mission reused a Fighter Control Center for an ADCC until the Type 4 Operations Building was ready for occupancy. In at least one instance, the AC&W program adapted a GCI station to serve as an ADCC until the Type 4 building was available. Air defense areas increased as buildout for the AC&W program moved forward, beginning with only four areas. CONAC assigned each area to a numbered Air Force. The air defense areas of July 1948-March 1949 mirrored the four of World War II, but with differing boundaries (Plate 73). By February 1950, two major air defense jurisdictions existed—the Western Air Defense Force and the Eastern Air Defense Force—with five broad air defense areas and one discrete fighter-managed zone (Plate 74). The air defense areas of 1950 were the 25th, 26th, 28th, 30th, and 32nd Air Divisions (Defense). They were extremely large, and their command posts managed geographic regions that would subdivide as new Air Divisions (Defense) came on line. The situation would be particularly confusing with regards to infrastructure for the 26th, 30th, and 32nd Air Divisions (Defense). The smaller FIS-protected zone, roughly circular and sited at Kirtland Air Force Base to provide air defense for Los Alamos, Sandia, and Kirtland, was unique. This area, for the 81st Fighter Wing, lasted only briefly. The Albuquerque Air Defense Sector (Provisional), and then the 34th Air Division (Defense), replaced it. By January 1951, the mosaic of air defense areas also included the 27th Air Division (Defense) in the West (Plate 75). As of July 1951, ADC (reestablished as a command by the Air Force in January that year) oversaw the 11 air defense areas as originally planned[37] (Plate 76). Air Divisions (Defense) remained constant at 11 between mid-1951 and 1955, but boundaries continued to shift[38] (Plate 77).

Physical construction roughly paralleled the sequential numbering of the air defense areas themselves, with the first two ADCCs reusing Fighter Control Centers on the West and East Coasts. The 25th Air Division (Defense), at Paine Field (Everett), Washington, became operational on 25 October 1948, followed by the 26th Air Division (Defense) at Roslyn, New York, on 16 November. At this time, Air Materiel Command had just completed the specifications for the command posts for the program (also known as the "technical buildings"). At Roslyn, the 26th Air Division (Defense) reused SOM's Fighter Control Center there until 1952, when the ADCC moved to a Type 4 Operations Building originally built to serve the 32nd Air Division (Defense) at Stewart Air Force Base to the west (but still in New York). Stewart hosted Headquarters Eastern Air Defense Force. At Paine Field, the 25th Air Division (Defense) also occupied an existing Fighter Control Center as its ADCC. Although not yet confirmed, the Fighter Control Center at Paine appears to have been a retrofitted school, rather than the standard SOM new construction of 1943-1944. As of 1951, the 25th Air Division (Defense) moved its ADCC to a Type 4 Operations Building at McChord Air Force Base, south of Tacoma.[39] Fluidity of boundaries for the air defense areas, as well as shifting use of the ADCCs, characterized the first months of the AC&W program. AC&W radar squadrons (as ADDCs) reported in groups of up to a half dozen to their regional ADCC. The assignment of AC&W radar squadrons to specific ADCCs changed many times throughout the air defense program. In a number of cases, ADC collocated ADDCs on Air Force installations with ADCCs. This was true at McChord for the 25th Air Division (Defense) and at Roslyn for the 26th Air Division (Defense), with the latter location combining the physical infrastructure of the World War II Fighter Control Center with the Type 2 ADDC designed by Holabird, Root & Burgee. Later in the program, collated ADCC and ADDCs also existed for the 28th Air Division (Defense) at Hamilton Air Force Base near San Francisco, the 31st Air Division (Defense) at Fort Schnelling in Minneapolis, the 33rd Air Division (Defense) at Tinker Air Force Base in Oklahoma City, and the 35th Air Division (Defense) at Dobbins Air Force Base in Marietta, Georgia (see below).

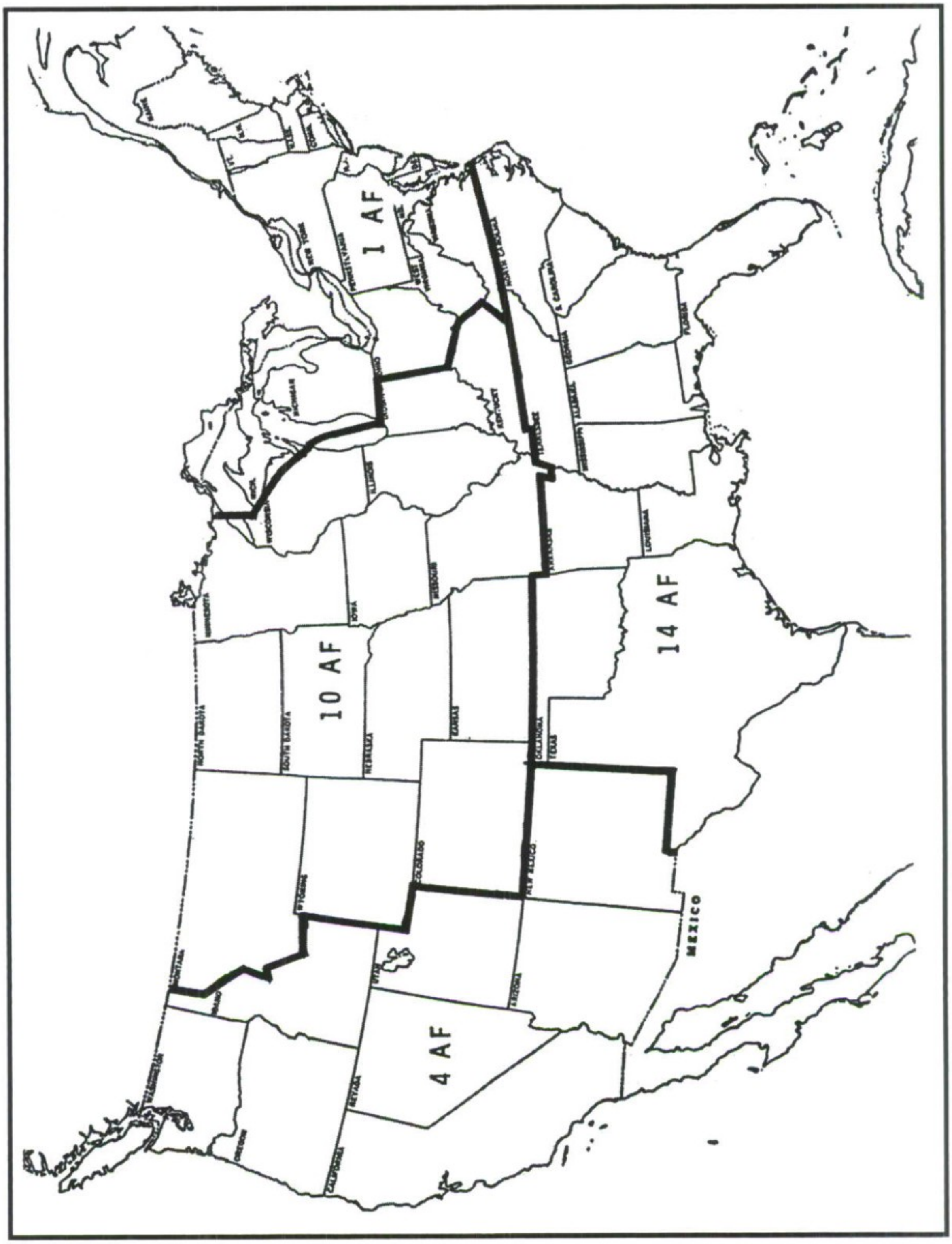

Plate 73: Areas of Responsibility for Air Defense, July 1948 – March 1949. In *Fifteen Years of Air Defense*, 1962.

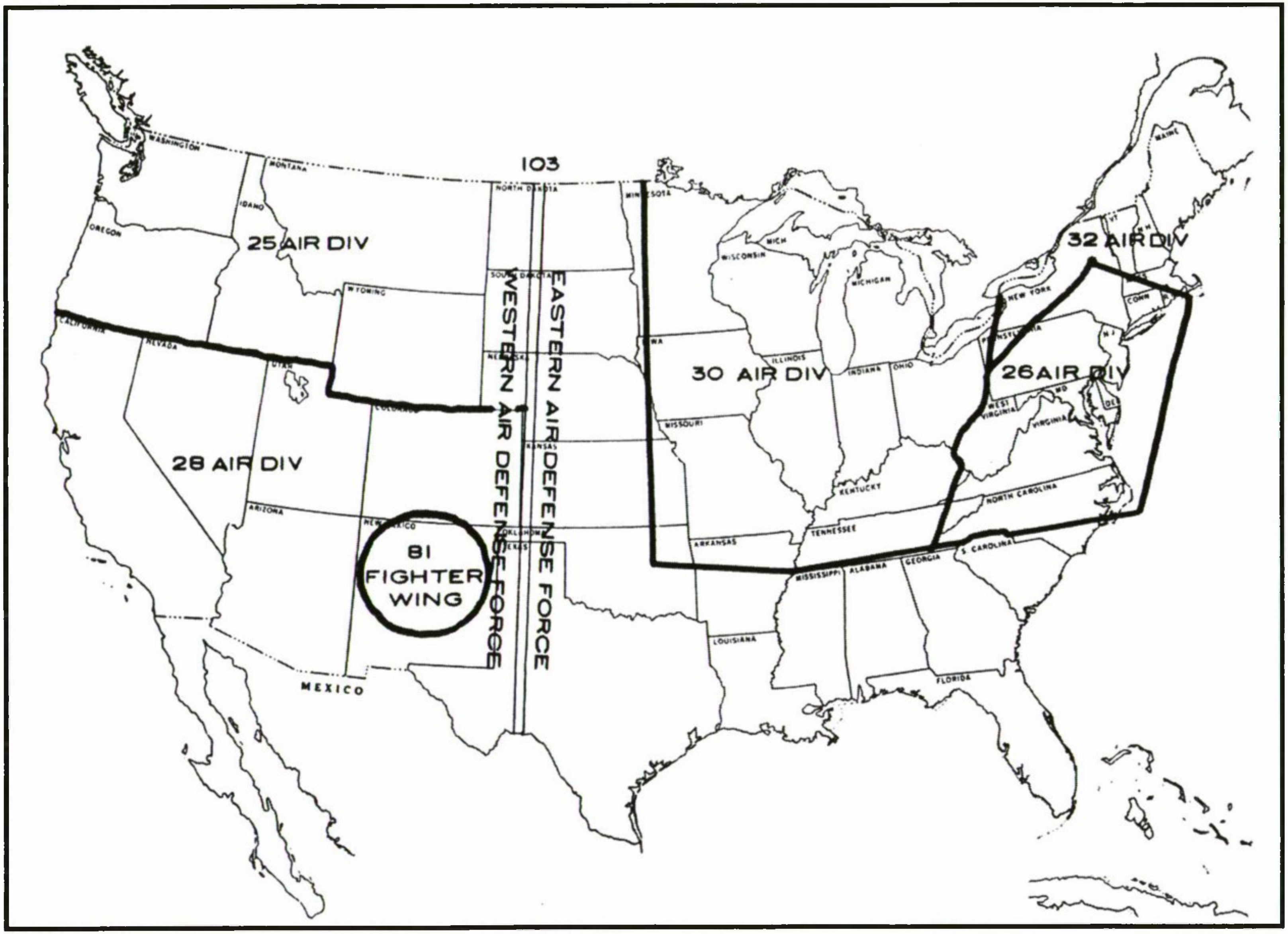

Plate 74: **Areas of Responsibility for Air Defense, February 1950. In *Organization and Responsibility for Air Defense March 1946 – September 1955.***

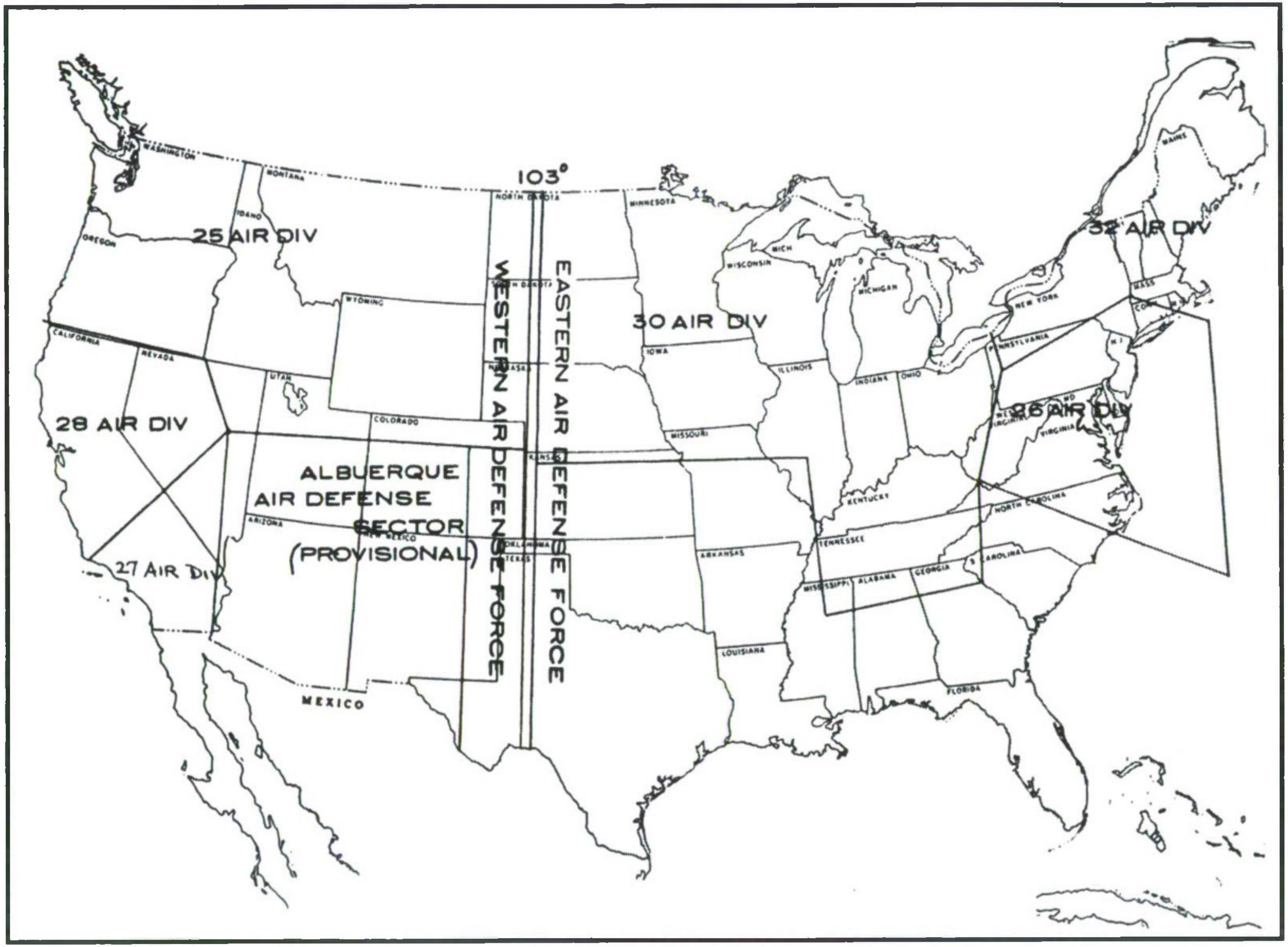

Plate 75: **Areas of Responsibility for Air Defense, January 1951. In *Organization and Responsibility for Air Defense March 1946 – September 1955.***

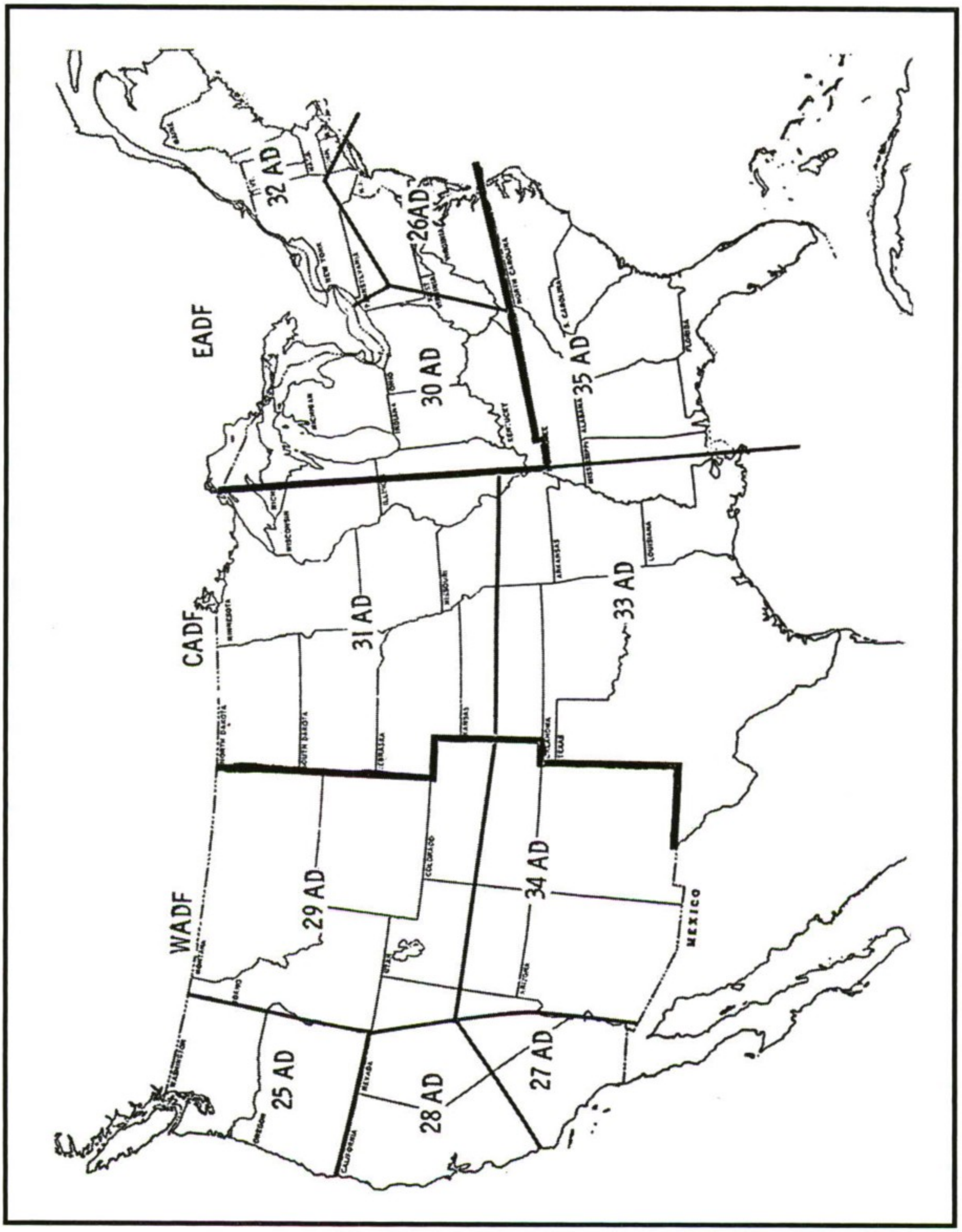

Plate 76: Air Force Areas of Responsibility for Air Defense, July 1951. The bolded boundary lines delineate the jurisdictions of the Western Air Defense Force (WADF), the Central Air Defense Force (CADF), and the Eastern Air Defense Force (EADF). In *Fifteen Years of Air Defense*, 1962.

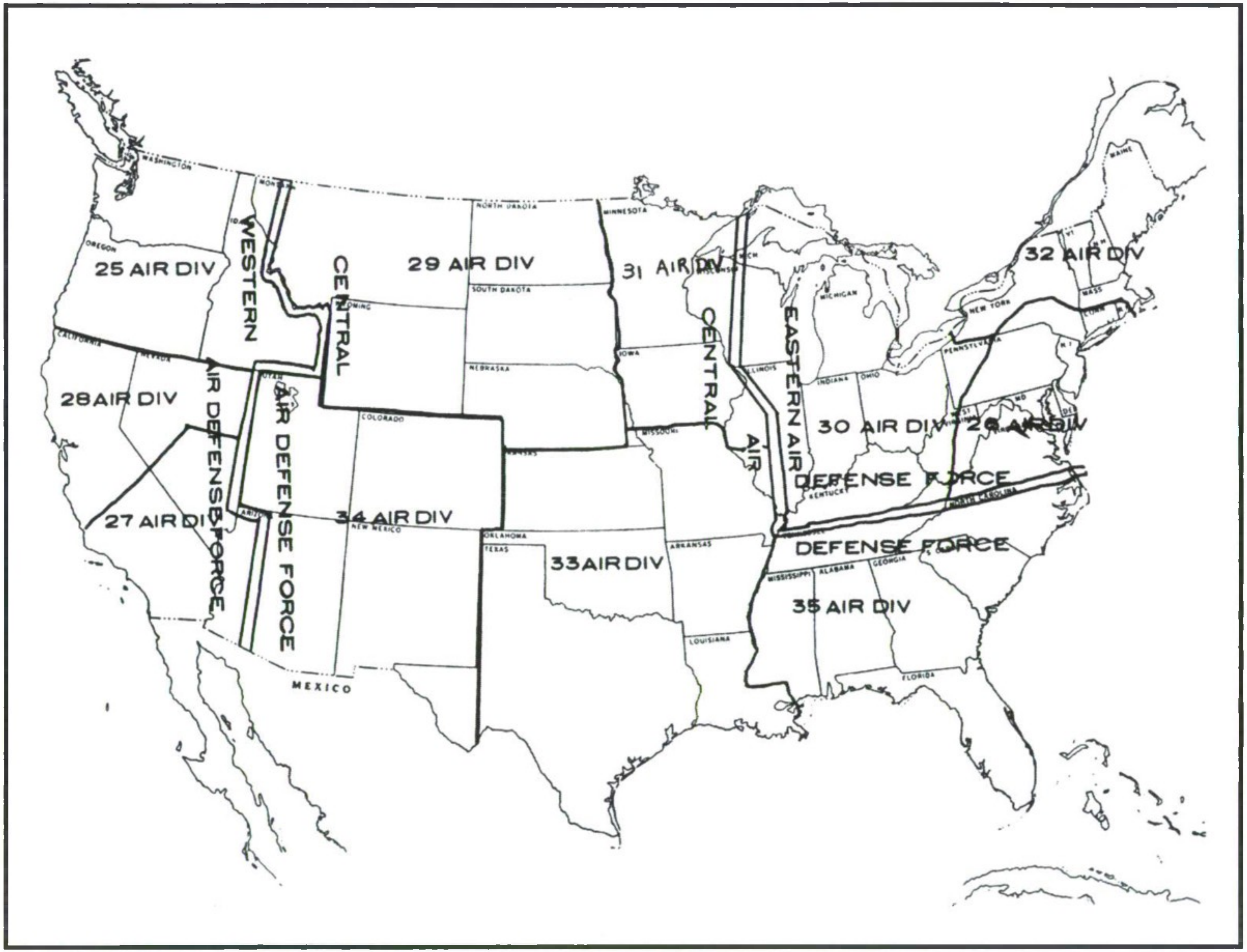

Plate 77: **Areas of Responsibility for Air Defense, February 1953. In *Organization and Responsibility for Air Defense March 1946 – September 1955.***

ADC activated the next western ADCC for the 27th Air Division (Defense) during autumn 1950, first using a GCI station at Fort MacArthur in Los Angeles as its temporary facilities. Fort MacArthur's GCI soon functioned as a permanent AC&W radar squadron (the 669th). During these early months, stations with AC&W Type 1 and 2 Operations Buildings, such as at Fort MacArthur, fluctuated in air defense assignment from EWSs to GCI stations. AC&W radar stations all had the infrastructure to sustain assignment as ADDCs. Once at Norton in December, the 27th Air Division (Defense) still remained in temporary quarters until the Type 4 Operations Building was ready for occupancy in late 1951. The interim Norton ADCC was physically separate from the permanent control center on base. Associated AC&W radar stations built out in the early 1950s included ones at Norton and Edwards Air Force Bases. AC&W radar stations also occupied temporary quarters—often, prefabricated Jamesway hutments—while awaiting the completion of the permanent Type 1 and 2 Operations Buildings. The 750th AC&W Squadron at Edwards operated a temporary station on base until completion of its permanent station at Atolia (Boron). A related issue for the startup of both the temporary and permanent command posts was receipt of interior equipment. Configurations of the operations rooms in the Type 2 and 4 buildings (the war rooms for the ADDC and the ADCC) were highly standardized, with shippable, prefabricated balconies set up around horizontal plotting (map) boards. The operations rooms of the ADCCs and the ADDCs looked identical whether functional inside makeshift quarters such as the World War II temporary buildings first assigned at Norton or within the permanent Type 2 and 4 buildings (Plate 78; see also, Plate 55).

Construction continued on ADCCs during 1950-1951, with a focus on the eastern and western United States. In the West, the Air Force activated the 28th Air Division (Defense) in December 1949 at Hamilton Air Force Base, north of San Francisco in Marin County. The 28th Air Division (Defense) was operational in its permanent Type 4 building as of early 1951. The 542nd AC&W Group managed the 28th Air Division (Defense) ADCC. Seven AC&W squadrons, each at a radar station, reported to the group. Selected of the radar stations hosted ADDCs. The AC&W squadrons of the

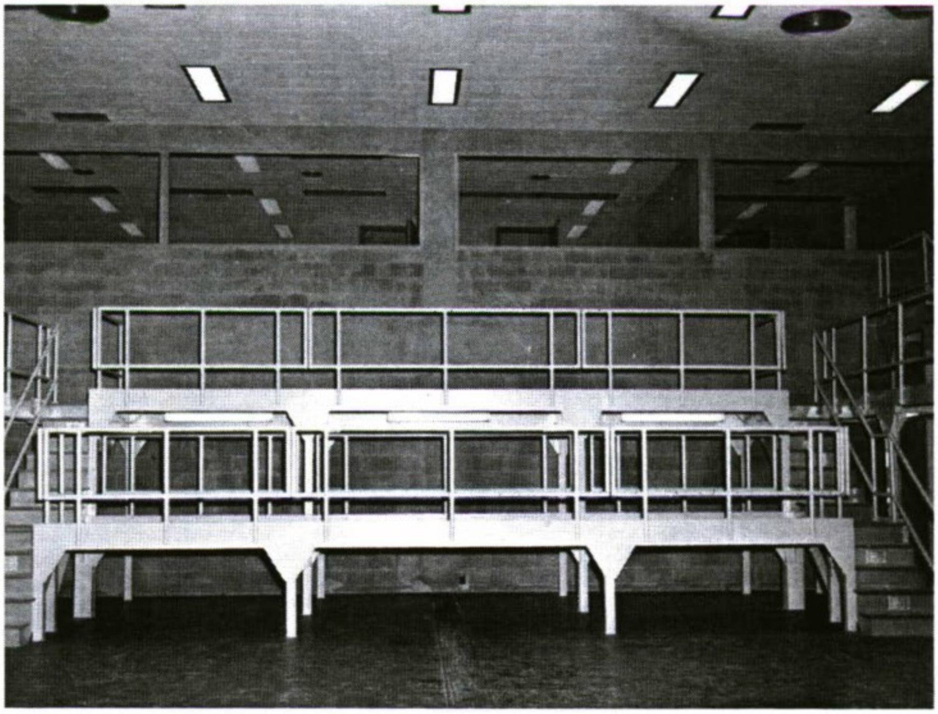

Plate 78: Dais and Observation Rooms overlooking the War Room inside the Type 4 Operations Building, 27th Air Division (Defense), Norton Air Force Base, 1950. In *History of the 27th Air Division (Defense) 1 January – 31 March 1951*.

28th Air Division (Defense) were located at Mather Air Force Base in Sacramento, as well as on Mount Tamalpais and Point Arena, and in Madera, Cambria, and Klamath, California. The 667th AC&W Squadron operated the ADDC collocated at Hamilton. AC&W radar squadrons sited on Air Force bases tended to be fenced as secured and segregated areas, with a larger compound of ancillary structures required when located as fully independent Air Force Stations. As of July 1952, American air defense also included a return to civilian spotters, with the establishment of the Ground Observer Corps and the reinstitution of Filter Centers. A combination of civilian and military personnel manned Filter Centers. The interiors of these facilities resembled the war rooms of the Type 2 and 4 Operations Buildings, but the Filter Centers themselves were not protective construction. By October 1953, a network of 73 Filter Centers was in place, all in cities "where the telephone companies have their toll terminals."[40]

Two additional air defense areas comprised the full jurisdiction of the Western Air Defense Force, with permanent infrastructure completed for each during 1951-1952. Construction of the ADCC and its support structures for the 29th Air Division (Defense) began in mid-1952, with completion at the end of October. The achievement of extremely quick operational status was typical for ADCCs once construction was underway. The relatively small size of the ADCC, as well as its standardized interior set up, contributed to the speed. The 29th Air Division (Defense) covered the five-state area of Montana, Wyoming, North and South Dakota, and Nebraska, with the ADCC located at Great Falls (today, Malmstrom) Air Force Base. Five AC&W radar squadrons reported to the ADCC. The fifth and final Air Division (Defense) for the Western Air Defense Force was the 34th, sited at Kirtland Air Force Base in Albuquerque. The Kirtland ADCC was under construction as of early 1951 and was operational within the year (Plate 79). For a brief period, the 690th AC&W squadron was also on base in Jamesway hutments. The Air Force planned the ADCC in Albuquerque as one of the earliest for the network. Its circularly-configured air defense zone of early 1950 was unique, run as a jurisdiction

Plate 79: ADCC, 34th Air Division (Defense) (Building 909), Kirtland Air Force Base, 1950. In *Historical Data 34th Air Division (Defense) 1 January – 31 March 1951.*

of a fighter wing. The unnumbered provisional area of January 1951 that followed was equally unusual (see Plates 74-75). Kirtland's status for a permanent ADCC, however, had fluctuated during 1949-1950 at Headquarters CONAC, Mitchel Air Force Base. In January 1950, CONAC had recommended that the future ADCC for Kirtland be replanned for Fort MacArthur in Southern California.[41] Ultimately, both general locations received ADCCs: at Norton for the 27th Air Division (Defense) and at Kirtland for the 29th Air Division (Defense) (see Plates 54 and 79). Fort MacArthur, as already discussed, hosted a reporting radar station.

At the outset of the 1950s, ADC interpreted the central and southeastern United States as those regions of the country least requiring coverage against air attack from Soviet bombers. The Central Air Defense Force had three air defense areas within its jurisdiction between 1950 and 1955: the 31st, the 33rd and the 35th Air Divisions (Defense). The 31st Air Division (Defense) covered five upper Midwestern states, along with parts of four additional states at the southern and eastern edges of its initial boundaries. The 33rd Air Division (Defense) had responsibility for an equally large geographic area from central Kansas south to the Gulf of Mexico, including four entire states and parts of five others. The 35th Air Division (Defense) monitored the Southeast. Its jurisdiction extended into seven states. The 31st Air Division (Defense) is yet another instance of first operations in make-shift quarters. CONAC activated the Division on Selfridge Air Force Base outside Detroit in October 1950, actually on the site of the 30th Air Division (Defense) to the east. After about four months, the 31st Division (Defense) moved into temporary quarters within its geographic air defense area: at the Naval Air Station adjacent to Wold Chamberlain Field in Minneapolis (the city airport). A permanent ADCC and its ancillaries were in construction by that date at the neighboring Fort Schnelling, with occupancy by 1952. No fewer than 13 AC&W squadrons reported to the 543rd AC&W Group (the ADCC) at Fort Schnelling, with one of these collocated at the Army installation. (In 1953, ADC selected the Type 2 Operations Building of the 789th AC&W Squadron at Omaha, Nebraska, as an alternate ADCC for that at Fort Schnelling.[42]) The 33rd Air Division (Defense), with its ADCC near Tinker Air Force Base in Oklahoma City, also first operated in temporary facilities on base. The 33rd Air Division (Defense) moved onto its independent site in August 1951. The 33rd Air Division (Defense) was yet another instance of an ADCC and ADDC at a shared location. The 35th Air Division (Defense) was under construction in late 1951 at Dobbins Air Force Base in Marietta, Georgia and was operational in early 1952. Again, ADC placed an ADDC on site.

Although geographically the smallest of the air defense areas during 1949-1953, that of the Eastern Air Defense Force also included three Air Divisions (Defense): the 26th at Roslyn, first in the existing Fighter Control Center and then moved to Stewart Air Force Base; the 30th; and, the 32nd. Both the 30th and the 32nd held down dual jurisdictions while ADCC construction was in progress at other locations. CONAC activated the 30th Air Division (Defense) at Selfridge Air Force Base in December 1949, with a temporary ADCC operational by autumn 1950 in an existing World War II structure. *Both* the 30th and 31st Air Divisions (Defense) operated at Selfridge in an *ad hoc* ADCC set up for remainder of the year, although neither would have their permanent ADCC at that base (for the 31st, see above). As of about January 1952, the 30th Air Division (Defense) received its Type 4 Operations Building 18 miles from Selfridge at the Willow Run airport southwest of Detroit. The permanent location abutted the World War II Martin bomber plant at Willow Run, as well as the University of Michigan's Willow Run Research Center of this identical period. CONAC also activated the 32nd Air Division (Defense) in December 1949, with its ADCC under construction before the close of the year and operational in early spring 1950. The Stewart ADCC for the 32nd Air Division (Defense) was the very first Type 4 Operations Building on line for American Cold War air defense. The 32nd Air Division (Defense) had a second ADCC under construction in 1951 at an entirely different site, adjacent to Hancock Field at Syracuse in upstate New York. The 32nd Air Division (Defense) moved to that site when the Type 4 Operations Building was ready for occupancy, vacating its first ADCC for the 26th Air Division (Defense). The 26th had been operating in the World

War II Fighter Control Center at Roslyn. The shuffling and overlapping command posts of the Eastern Air Defense Force during the late 1940s and early 1950s is an excellent example of the complexity of the air defense command post network at the outset of the Cold War.

ADC undertook sophisticated research toward computerizing air defense command, control, and communications (C^3) simultaneously with the buildout of the ADCCs and ADDCs during 1949-1952.[43] At the Massachusetts Institute of Technology (MIT), mathematicians in its Digital Computer Laboratory initiated R&D for computers that could support radar and other military systems. MIT began efforts for the Electronic Numerical Integrator and Calculator (ENIAC) during 1945. The Army used ENIAC at the Aberdeen Proving Ground to assist in the millions of calculations needed for experimentation toward the atomic bomb. Later in 1947, MIT undertook Project Whirlwind which employed advanced computer technologies to aid the Office of Naval Research in analysis of aircraft stability. MIT soon envisioned that Whirlwind could be adapted to receive radar pulses, and later on could calculate aircraft speed, direction, and distance for coordination of the fighter-interceptor air defense mission. Also in 1947, MIT proposed testing Whirlwind in this role as a part of the Cape Cod Air Defense System. After courting the Air Force for additional R&D monies, MIT dedicated Whirlwind solely to air defense planning. As of 1950, the Valley Committee (under George E. Valley of MIT) looked further at the state of air defense and the possible future role of computerized capabilities, especially for issues of command and control. Project Charles followed, headed at MIT by F. Wheeler Loomis while on leave from the University of Illinois (see Volume II, Chapter 5).

Before the close of 1951, RAND corroborated the findings of Project Charles, and MIT established Project Lincoln. MIT staff operated Lincoln as an air defense laboratory (the Lincoln Laboratory) adjacent to the Cambridge Research Laboratories (Center) at Hanscom Air Force Base. The Air Force backed Project Lincoln (as the Lincoln Transmission System) during 1951-1952. The agency also supported an alternate university air defense project, the Air Defense Integrated System (ADIS), through the University of Michigan at its Willow Run Research Center. Michigan's ADIS directly adapted aspects of the British Royal Navy's Comprehensive Display System (CDS) to American radar. The University of Michigan and MIT argued for greater and lesser command posts, respectively, with one university using the term Control Center and the other, Direction Center. Neither university as yet described a two-tiered system (as was already going in place with the ADCCs and ADDCs). The two programs differed in other ways as well, with the Air Force stipulating that each university approach the air defense problem from specific points of view. In May 1953, the Air Force dropped the Michigan study and gave the go-ahead to MIT to augment its Cape Cod test model for a real military environment. In 1954, ADC built a Combat Operations Center at Ent Air Force Base in Colorado to coordinate the existing system of AC&W ADCCs and ADDCs while work toward the next generation of command and control centers continued.

As ADC prepared to computerize its command and control operations in 1955-1957, the command augmented its first 11 ADCCs with an additional five for improved control. The new ADCCs necessitated a redrawing of the boundaries for air defense areas, with most made much smaller (Plate 80). The planned timeframe for conversion to SAGE was 1956 to 1958, but in fact construction was very slow with SAGE command posts coming on line during 1958-1960. The five added ADCCs were really only placeholders, between one era of air defense and another. In some cases, the middle 1950s ADCCs were in construction not only side-by-side with SAGE compounds, but at the same time. These supplementary ADCCs were streamlined in their design and engineering, anticipated as extremely short-lived. Drawings for these ADCCs show that the Air Force elected to delete key features for gas-proofing against biological and chemical warfare, although the buildings were still standard Type 4 Operations command posts. When revised, the most noticeable change was the lack of a ventilating tower.

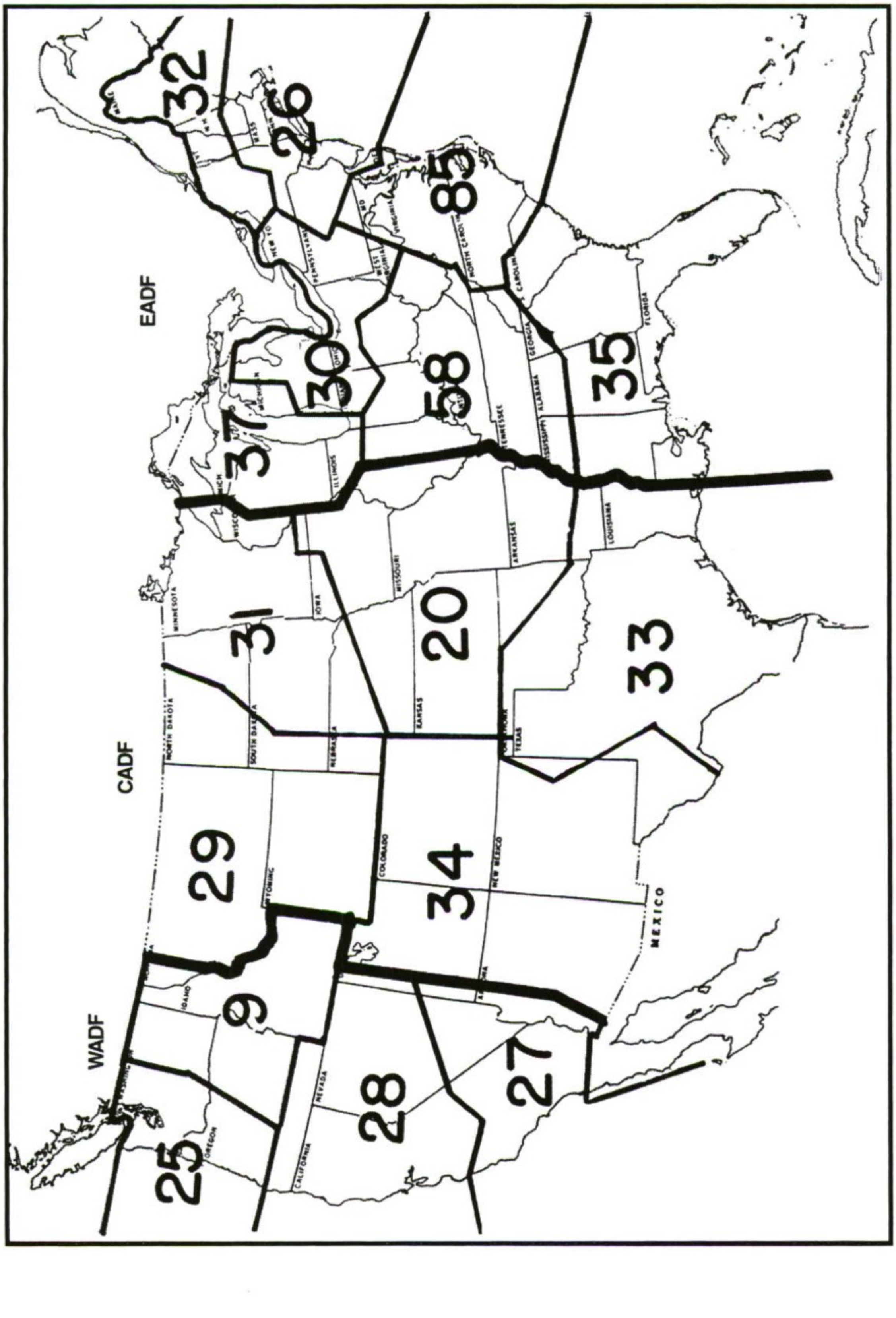

Plate 80: Areas of Responsibility for Air Defense, 8 October 1955. ADC scheduled the new divisions (9th, 37th, 58th, and 85th) to assume air defense duties in early 1956. In *Organization and Responsibility for Air Defense March 1946 – September 1955.*

From east to west, the ADCCs of the middle 1950s were the 85th, 58th, 37th, 20th, and the 9th (see Plate 80). ADC issued general orders for the activation of the 85th, 58th, and 37th Air Divisions (Defense) in September 1955, with construction of modified Type 4 Operations Buildings underway before that date. The Air Force considered these three only temporary operations, likely to be discontinued in 1959 with the SAGE takeover of air defense responsibilities for their regions. The ADCC for the 58th Air Division (Defense) was the first under construction. ADC adapted it for Wright-Patterson Air Force Base in December 1954,[44] with the Type 4 Operations Building ready for occupancy the next year. The ADCCs for both the 37th and 85th Air Divisions (Defense) were under construction in late 1955. These two command posts came on line in spring 1956. In the case of the ADCC for the 37th Air Division (Defense), built at Truax Air Force Base in Madison, Wisconsin, construction was literally simultaneous with that for SAGE. The ADCC and SAGE compounds were across a street from one another within the same physical area. A similar situation existed for the ADCC of the 85th Air Division (Defense) at Andrews Air Force Base in Camp Springs, Maryland. The ADCC and its ancillary buildings (a power plant and administrative office) were in construction at the same time as the SAGE Direction Center for the region, which was at Fort Lee in Petersburg, Virginia (Plates 81-82).

ADC sited the ADCCs for the 9th and 20th Air Divisions (Defense) at Geiger Field in Spokane, Washington, and Grandview (after 1957, Richards-Gebaur) Air Force Base in Kansas City, Missouri. The ADCC at Gieger became operational in December 1954 and was actually the first of the five middle-1950s ADCCs to do so. The Grandview ADCC was not operational until late autumn 1955. Of note, the ADCC at Grandview retained its original Type 4 Operations Building design, including its ventilating tower and gas-proofing features. ADC built a SAGE Direction Center at Larsen Air Force Base, to the southwest of Spokane at Moses Lake, Washington, during the later stages of construction for the SAGE program. At Grandview, a SAGE Direction Center was under construction by 1956, collocated with the ADCC of 1955. The Grandview / Richards-Gebaur SAGE initially served as a test and training center, with the ADCC continuing to function as an air defense command post. At mid-decade, the ADCC at Grandview hosted both the 20th Air Division (Defense) for ADC and the Central Antiaircraft Regional Command (ARAACOM) for the Army. After SAGE took over Air Force air defense responsibilities for the region in 1957, the ADCC continued as an Army command post for the 4th Region Army Air Defense Command (ARADCOM). In 1961, the Richards-Gebaur ADCC became the command post for the 2nd Region ARADCOM. The Army deactivated the Richards-Gebaur ADCC as an air defense command post in 1969.[45]

The Air Force also built ADCCs on territorial and foreign soil. Command structure and operation of these ADCCs was somewhat different than for the 16 command posts protecting the continental United States. The earliest of these ADCCs were two in Alaska. The Air Force had planned for two command posts in Alaska from the outset of the program in 1949-1950. Alaskan Air Command established both ADCCs and ADDCs for Elmendorf and Ladd Air Force Bases. The 10th Air Division (Defense) activated in November 1952 at Elmendorf in Anchorage. The 11th Air Division (Defense) followed in April 1953 at Ladd in Fairbanks. As early as late 1950, however, some form of air defense command and control had been in place. Throughout most of the decade Alaskan Air Command improvised the Elmendorf and Fairbanks command posts in existing or prefabricated buildings. The 10th Air Division (Defense) ADCC was a Jamesway hutment in a cleared area five miles north of the Elmendorf runway. The division's ADDC used the basement of a 500-man permanent barracks on base. By spring 1956, the Air Force planned a permanent ADCC for the 10th Air Division (Defense) at Elmendorf, but did not anticipate occupancy until 1958-1959. For the 11th Air Division (Defense), Alaskan Air Command sited the ADCC at Clear, Alaska, to the southwest of Fairbanks. Its ADDC was in temporary quarters at Ladd.[46]

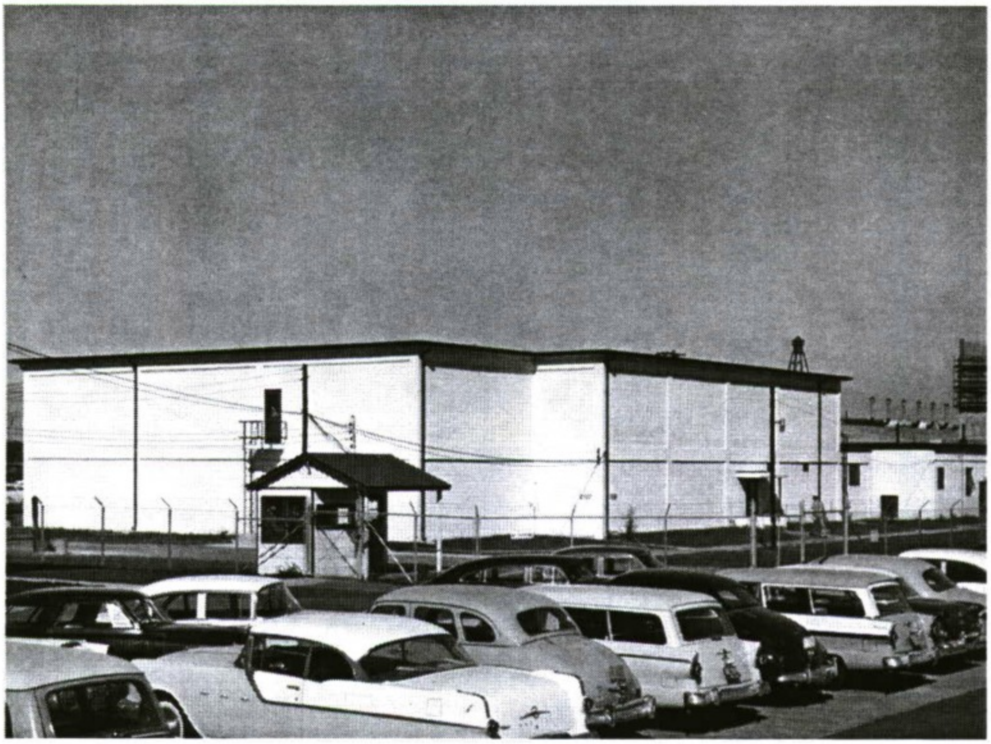

Plate 81: Modified Type 4 Operations Building, ADCC, 37th Air Division (Defense), Truax Air Force Base, 1956. In *History of the Joint 37th Air Defense Division and 37th Air Division (Defense) March – June 1956*, volume 1.

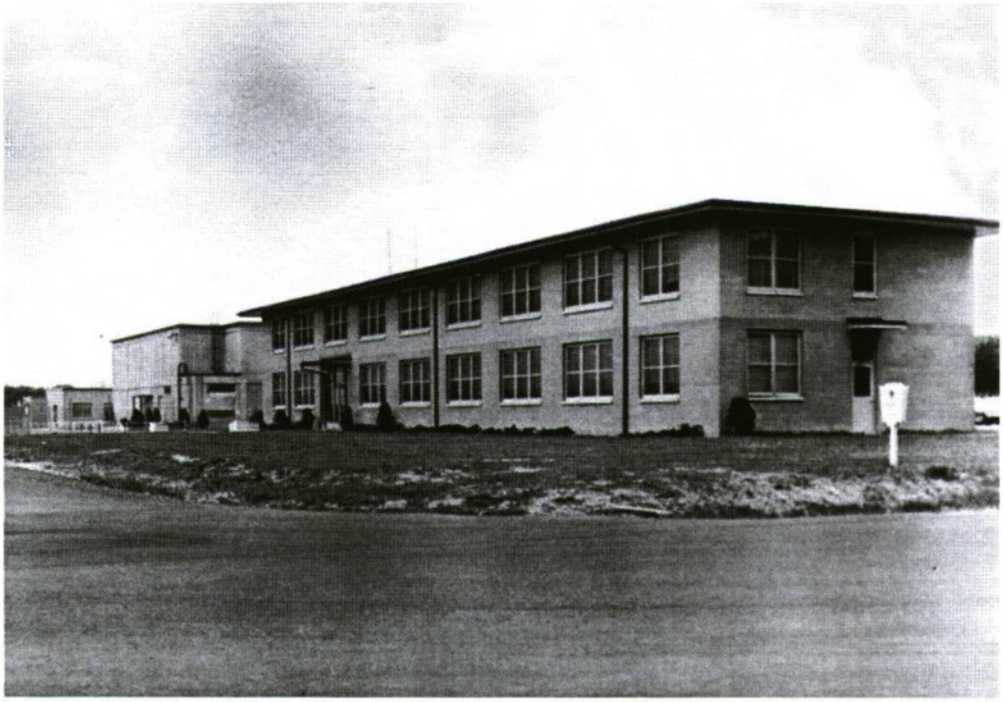

Plate 82: Type 3 Operations Building (foreground) and Modified Type 4 Operations Building (ADCC) (background), 85th Air Division (Defense), Andrews Air Force Base, 1956. In *History of 85th Joint Air Defense Division and 85th Air Division (Defense) July – December 1956*, volume 1.

The ADCCs built overseas were also unusual. That for the 41st Air Division (Defense) at Johnson Air Base near Yokota, Japan, managed air defense for the Japan Air Defense Force by March 1952. An alternate ADCC was in place at Shiroi as of mid-December. The Air Force established multiple AC&W radar stations and FIS alert squadrons across central Japan as well. By early 1954, the Far East Air Forces (FEAF) was building a new ADCC on Johnson Air Base that was "standardized in design with other ADCC's [*sic*] of the Japan Air Defense Force...[to] embody...equipment and facilities recommended by the Air Defense Command of the United States Air Force."[47] The provision for the ADC system of air defense command and control on Japanese soil is of unresearched specifics, but it fell at the end of American involvement in the Korean War. In spring 1952, Northeast Air Command (NEAC) activated the 64th Air Division (Defense) at an independent site six miles from Pepperrell Air Force Base in St. Johns, Newfoundland. An ADCC was in place by mid-1952, with at least some use of Jamesway hutments. The Pepperrell ADCC was in communication with British ADCCs built at other locations in Canada, as well as linked to the air defense system in the northeastern United States.

The remaining two ADCCs overlapped with SAGE directly and were not built until 1957 and 1960. By this date, the Air Force no longer used the Holabird, Root & Burgee designs for Type 1-4 Operations Buildings. Both of these late air defense areas were in Europe. During April 1957, the Sixteenth Air Force sited the 65th Air Division (Defense) in the Spanish Air Ministry building. The Division reported to SAC. As of the late 1950s, SAC established four key installations in Spain to park its bombers in a forward position to the Soviet Union and as refueling bases with major petroleum supplies. The 65th Air Division (Defense) managed a group of seven AC&W radar squadrons, fighter alert, and an ADCC. The situation was unique, with General Franco having established a separate Air Defense Command for Spain the year before. The American and Spanish air defense systems were not linked, and that of SAC was not officially tied to the existing early warning system of the North Atlantic Treaty Organization (NATO). SAC located the permanent ADCC on Torrejon Air Base, adjacent to the Sixteenth Air Force Headquarters. AC&W radar stations supported ADDCs in at least some of the locations. The Middletown AMA at Olmsted Air Force Base in Pennsylvania supplied and installed all of the communications equipment for the Torrejon ADCC. As of late 1958, SAC renamed its ADCC a Combat Center. The command posts at the radar stations remained Direction Centers, with the two—Direction and Combat Centers—offering an identical hierarchical system to SAGE. The staff of the Spanish Air Defense Command and that of the 65th Air Division (Defense) jointly occupied the war room of the Combat Center. The final Air Division (Defense) was the 86th, a NATO-affiliated unit operating under the Seventeenth Air Force as of November 1960 at Ramstein Air Base in Germany. Its Combat Center represented a new era, with a complex of not just FIS and radar, but also direct communications to other air bases and missile control. Hardened construction for both the Combat Center and the aircraft shelters for the NATO fighters was in the immediate offing, with the work carried forward through the Air Force Weapons Laboratory (AFWL) at Kirtland Air Force Base.

As the first network of air defense command posts achieved completion in the late 1950s, the next generation of infrastructure started coming on line—that of SAGE. Again, ARDC was central to this most important of air defense networks. SAGE established the need for using continuous-wave radars in conjunction with digital computers capable of handling very fast data transmission and analysis. MIT's George Valley had envisioned taking the data from many small radars and correlating it via computer. The process necessitated the shift from analog to digital computers, which in turn made possible many more thousands of arithmetic calculations per second. The IBM computers, configured in duplex at each command post, were the heart of SAGE. Initial planning for computerized air defense had evaluated the idea of placing SAGE in the existing Type 4 Operations Buildings, but ADC soon abandoned that idea. The computer equipment was simply too large, and prioritized air defense areas were changing in size and boundaries which made the Type 4 sites not

always optimal. Personnel stationed at SAGE centers analyzed early warning information forwarded from radar stations and other specialized outposts. They also directed FIS on 24-hour alert at the appropriate regional Air Force installations and coordinated Bomarc. The Bomarc guided missile was in development and test at a launch complex on Santa Rosa Island at Eglin Air Force Base as of the middle 1950s and was a high-profile program. Bomarc launch sites were under construction at multiple locations simultaneously with buildout for SAGE. While SAGE primarily addressed the Soviet bomber threat, the system also attempted to meet the needs of the missile era—focused on the guided missiles carried by enemy bombers and looking toward the ICBM.

The physical infrastructure continued the two-tiered organization of the ADCC and ADDC, but the numbers of command posts at each level shifted dramatically. SAGE buildings were reinforced concrete, very large, of simple shape, and windowless. These structures represented a next step in protective construction, although were not truly hardened. Engineers designed them against the effects of nuclear blast and radiation, using additional steel reinforcing disguised as pilasters on the exteriors of the first group of centers (as also had been engineered for selected telephone buildings as of the middle 1950s). The exterior walls, flooring, and roof varied in thickness from 10 inches to one foot, with the composition of the concrete as yet unresearched. The wall thickness offered protection from gamma rays, while concrete mixtures with specific additives offered substantially increased shielding from radiation via energized neutrons. The official *SAGE Operational Plan* of March 1955, known as the project's Red Book, stated that SAGE centers were "designed to be shock-resistant and contamination-proof."[48]

ADC oversaw the design of the very first SAGE center immediately adjacent to the Lincoln Laboratory of the early 1950s at Hanscom Air Force Base, under construction at mid-decade. The Hanscom SAGE functioned as a Direction Center and was responsible for the Experimental SAGE subsector. The Experimental SAGE Direction Center was first known as the XD (experiment digital [?])-1 Building (Plate 83). The text complex took its name from the XD-1 computer, the prototype for the AN/FSQ-7. While the Experimental SAGE Direction Center was under construction at Hanscom, pretests of the evolving SAGE system were underway at Stewart Air Force Base in New York as of mid-1955 using the Type 4 Operations Building of the 26th Air Division (Defense). The 4621st and 4622nd Air Defense Wings (SAGE), fighter-interceptor squadrons at McGuire and Stewart Air Force Bases, supported early SAGE testing from Stewart.[49] At Hanscom, ADC designated the 4620th Air Defense Wing (Experimental SAGE) at this same time. ADC configured the 4620th as a FIS, with a standard alert hangar and apron. The 4620th assisted ARDC in the operation of the experimental SAGE sector (run from the XD-1 Building), and tested electronics-communications links between the control center and scrambled fighter aircraft. Sequential testing for SAGE, before the system was officially operational, also occurred at the combined Combat-and-Direction Centers built at Hancock Field in Syracuse, New York, where an ADCC preexisted for the 32nd Air Division (Defense) (Plates 84-85).[50]

The SAGE project was extremely complex. Not surprisingly, SAGE ran over budget and behind schedule. As planning got underway, the numbers of command posts grew to 46, with a change to 42 by early 1954. As of mid-year, ADC shifted from the idea of single-level command centers—first termed Direction Centers for SAGE—to two tiers similar to the existing system of ADCCs and ADDCs. ADC named the sector level centers Combat Centers and the subsector level centers, Direction Centers. The command also requested that the mainframe computer for SAGE be designed as two different machines, one for each SAGE level, rather than a single identical IBM system. ADC added plans for nine Combat Centers to a program of about 40 Direction Centers. By early 1955, ADC and ARDC revised the numbers of SAGE centers again, downsizing the network to an anticipated eight Combat Centers and 32 Direction Centers (Plate 86). SAGE was in construction as of 1955, with the first three centers underway at McGuire and Stewart Air Force Bases in New Jersey

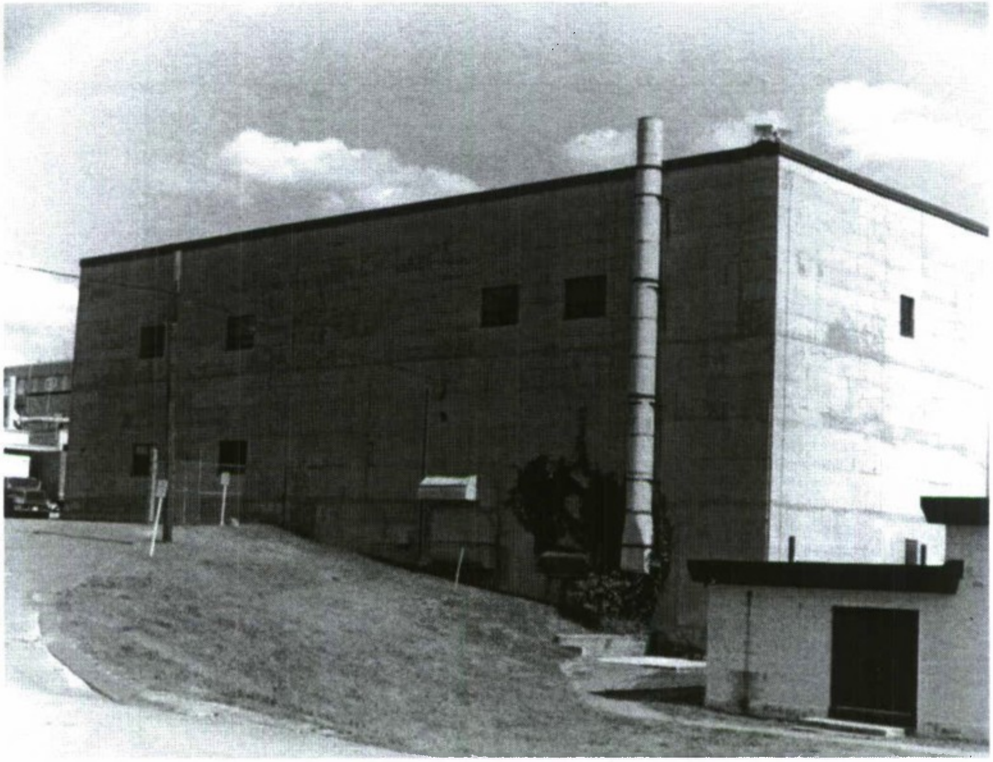

Plate 83: XD-1 Building, Experimental SAGE Direction Center (Building 1302F), Hanscom Air Force Base, 1956. Photograph of July 2000. K.J. Weitze for EDAW, Inc.

and New York, and at Fort Lee in Virginia. By 1956, construction began for four more SAGE command posts. Western Electric won the SAGE system contract, with the design and engineering for the centers subcontracted to Burns & Roe of New York. Burns & Roe designed Combat Centers as three-story buildings and Direction Centers as four-story buildings, with each requiring an independent power plant on site. The original design featured two variations. In one scenario, a combined Combat-and-Direction Center complex had a power plant directly attached. In the second, power plants were immediately adjacent, but were free-standing. For the latter, ADC still sited Combat and Direction Centers in a "combined" configuration, sharing a single power plant. The command located supporting Direction Centers, with their power plants, at separate installations within their respective Air Defense Regions. As the program changed during its buildout, both in size and somewhat in design, unusual command posts occurred. One such case was at Minot Air Force Base in North Dakota, where a combined Combat-and-Direction Center was in progress when ADC downgraded the location to a Direction Center only. At Minot, too, one story for each building was underground—possibly an adaptation for hardening. With its SAC mission, Minot offered a primary Soviet target. This was especially true as of the early 1960s with the construction of miles of neighboring intercontinental ballistic missile (ICBM) Minuteman silos.

As built, SAGE included three Combat Centers, evenly spaced across the continental United States, and 23 Direction Centers. ADC accepted work as completed for eight SAGE sites as of 1958. Early that year, the Department of Defense shifted construction management responsibility from the Air Force to the Army Corps of Engineers, with a cost-cutting simplification of building design. The first 12 SAGE centers included combined Combat-and-Direction Centers at McChord and Truax Air Force Bases, and at Syracuse Air Force Station. An ADCC from 1950-1951 existed on site at each of these installations. While ADC did not construct the ADCC and SAGE adjacent to one another at

Plate 84: ADCC, 32nd Air Division (Defense), Syracuse Air Force Station at Hancock Field, 1952. Photograph of July 2000. K.J. Weitze for EDAW, Inc.

Plate 85: Combat and Direction Centers, SAGE, Syracuse Air Force Station at Hancock Field, 1958. Photograph of July 2000. K.J. Weitze for EDAW, Inc.

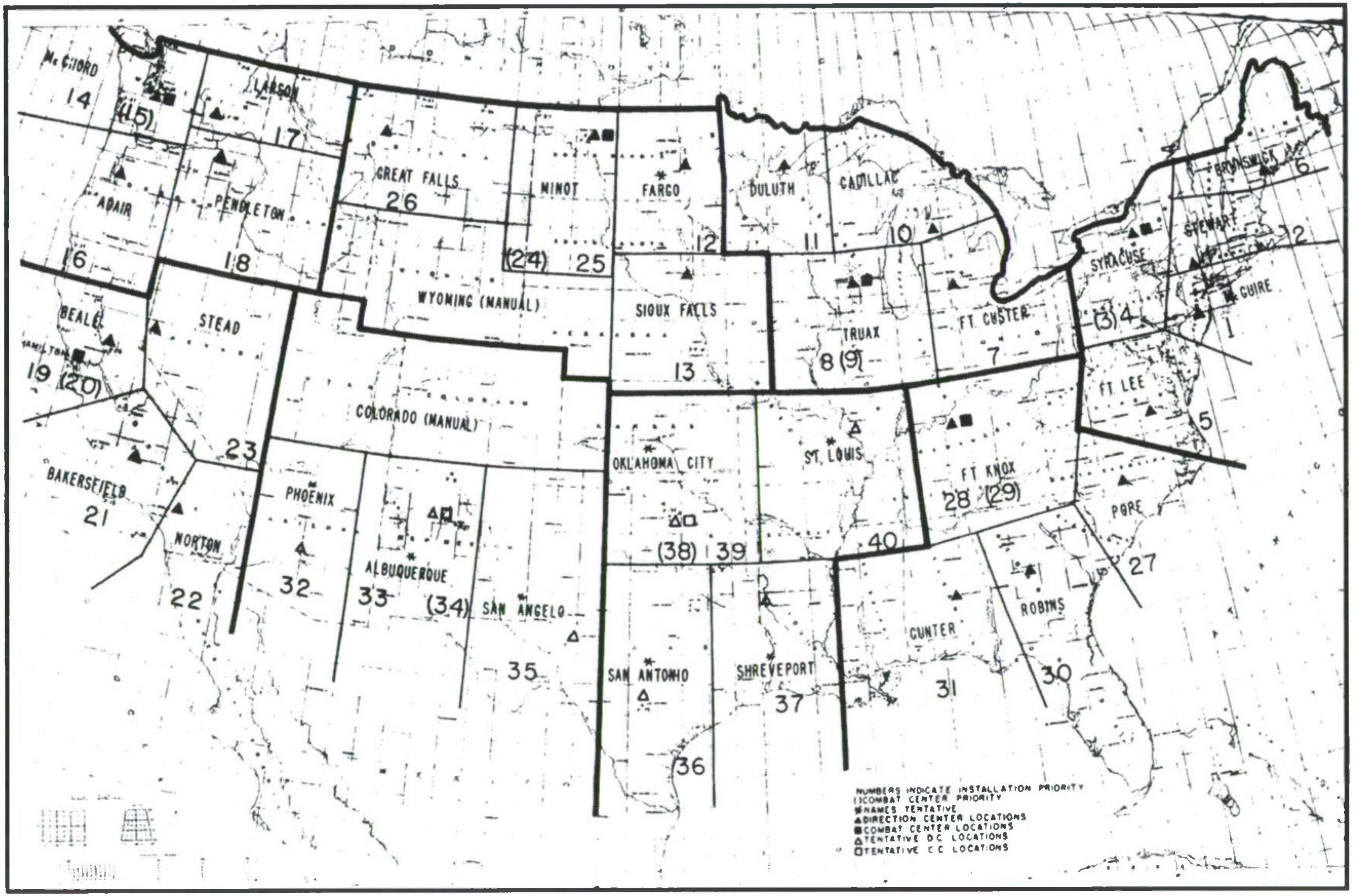

Plate 86: Plans for 40 SAGE Sectors, with anticipated Combat Centers (8) and Direction Centers (32), January 1955. Finalized as 23 SAGE sectors, with CCs (3) and DCs (23), including a manual DC in North Bay, Ontario, Canada (northeast of Detroit). Adapted from *Organization and Responsibility for Air Defense March 1946 – September 1955.*

McChord, this was the case at Truax and Syracuse where the overall air defense compounds were very close knit. The other initial nine SAGE command posts were all Direction Centers, located at McGuire Air Force Base (New Jersey), Stewart Air Force Base (New York), Fort Lee (Virginia), Topsham Air Force Station (Maine), Fort Custer (Michigan), Grandview [Richards-Gebaur] Air Force Base (Missouri), Gunter Air Force Base (Alabama), Duluth Air Force Station (Minnesota), and Grand Forks Air Force Base (North Dakota). Of these SAGE Direction Centers, those at Stewart and Grandview were collocated with ADCCs from the first Cold War air defense command-post network. ADC sited the facility at Fort Custer (at Custer Air Force Station) just west of Battle Creek so that is was separate from the ADCC at Willow Run to the east (but remained regionally proximate). Also at Fort Custer was an AC&W radar station from the early 1950s. All of these first SAGE facilities featured a pilastered exterior finishing, while those completed after 1958 did not. The SAGE Direction Center at Grand Forks appears to be the transitional compound. The center includes both simplified pilasters and the visible alternating square-panel treatment of the second group.

By late 1958, the SAGE program left its testing phase behind. ADC and MIT closed the Direction Center adjacent to the Lincoln Laboratory at Hanscom which had been built as the Experimental SAGE command post. The remaining 11 SAGE Direction Centers were each under construction. Personnel from the Experimental SAGE Direction Center moved to operational facilities at Air Force installations or to the Systems Development Corporation affiliated with RAND in Southern California. The Butler-building laboratory complex at Hanscom, sited between the Lincoln Laboratory and the Cambridge Research Center in 1956 to house the RAND personnel working on SAGE, also ceased its original use (see Volume I, Part III). The first SAGE command post to come on line was that at the Syracuse Air Force Station, with its combined Combat-and-Direction Center operational as of December 1958 (see Plate 85). The Syracuse facilities conducted final testing for SAGE after the closure of the Experimental Direction Center at the Lincoln Laboratory. As a subinstallation of Griffiss Air Force Base to the east, the Syracuse SAGE compound maintained ties to the RADC—once again demonstrating the continuous roles of Hanscom and Rome in the R&D process for Air Force air defense during the period of 1948-1960. At this same time, North American Air Defense Command (NORAD) and ADC began to realign the manual (ADCC / ADDC) air defense area boundaries to the SAGE configuration, simultaneously phasing out the first-generation command posts. From this point forward, the Air Force referenced the ADCC / ADDC network as "manual" and SAGE as "automatic," deriving these labels from their distinctions in communications: the earlier network was not computerized.

The use of actual command posts predictably remained highly fluid as the air defense system transitioned from the ADCC / ADDC network to SAGE. The final SAGE Direction Centers built in the United States were at K.I. Sawyer Air Force Base (Michigan), Sioux City Air Force Station (Iowa), Minot Air Force Base (North Dakota), Malmstrom Air Force Base (Montana), Luke Air Force Base (Arizona), Stead Air Force Base (Nevada), Beale and Norton Air Force Bases (California), Camp Adair (Oregon), and Larsen Air Force Base (Washington). The twenty-third Direction Center went in at North Bay, Ontario, in Canada to the northeast of Detroit. The North Bay SAGE command post was the only one designed as manual (initially without the IBM duplex computers) and was fully hardened—built inside the rock of a mountain site. During 1959, the Joint Chiefs of Staff also authorized the complete hardening of the NORAD command operations center in Colorado. NORAD's new command post had been in design since 1956, with the underground operations center built in Cheyenne Mountain. Of the final SAGE Direction Centers, ADC collocated those at Malmstrom and Norton with an ADCC of the previous air defense generation. The actual operational status across SAGE was uneven. Although physically complete, the combined Combat-and-Direction Centers at Truax and McChord, for example, were not fully on line until September 1959 and May 1960, respectively. At selected ADCC sites, ADC designated "remote combat centers" and manual SAGE centers to augment the very small actual buildout of SAGE Combat Centers (three, down from

the nine originally planned). The ADCCs at Hamilton and Richards-Gebaur (Grandview) functioned in this manner for a period of time, as did the ADCCs at Tinker, Kirtland, and Malmstrom.[51] Six ADCCs continued in an administrative function for SAGE. This situation was typical when ADCCs were collocated on site with SAGE structures.

As sophisticated as it was, SAGE witnessed its own accelerated obsolescence due to the extremely fast pacing of the Cold War arms race after 1960. While the duplex IBM computers were truly impressive, capable of generating 200 different displays every 2.5 seconds with 65,000 computations per second required to achieve each of these informational fields, simulated bomber attacks by SAC also illustrated that SAGE was only effective for air defense under optimal conditions. In varied ways, the enemy could get past SAGE detection. In addition, the change from chiefly a bomber threat to one focused on increasingly destructive and accurate ICBMs, also shifted the dynamics of the air defense command and control equation. For a brief period during 1958-1960, ADC planned for a new command post network that featured nine to 10 Super Combat Centers, even as SAGE was just coming on line. Each of the Super Combat Centers was to be 300 to 500 feet underground. Super Combat Centers were to use a smaller, next-generation computer capable of handling as much as seven times more data. An initial scheme called for two to four Direction Centers to report to each of the Super Combat Centers. All efforts for the Super Combat Center program were preliminary, with the very expensive centers aborted in early 1960. ADC was especially worried about the ICBM threat and next conceived the idea of widely dispersing its command post network. This follow-on air defense command and control system, the Back-Up Interceptor Control (BUIC) network, reused the ADDCs designed by Holabird, Root & Burgee in 1949.

BUIC increased the number of potential air defense command post targets for the Soviet Union, with the intent that destruction of some posts would not knock out the system. Dispersal and redundancy were among the key tactics of the program. A center at one location could take over for another, paralleling the original principal of ADCCs and ADDCs. Redundancy and alternate choices were also the guiding rationales for the manual SAGE centers that backed up SAGE. ("Manual SAGE centers" were really continuing ADCCs, housed in selected Type 4 Operations Buildings.) By the early 1960s too, smaller computers made the very large infrastructure of SAGE unnecessary, while increased ICBM threat made any targeted air defense command post unlikely to survive without hardening below ground. The extremely high costs of the Cold War, particularly with the beginnings of the ICBM program during the late 1950s, also directed air defense attention to a creative solution of lowered expense. The Air Force chose to review its AC&W radar stations, focusing on the Type 2 Operations Building. Protective construction, the Type 2 building was also extant in sufficient numbers to allow good site selection for BUIC (something not true of the Type 4 Operations Building, its counterpart). In 1960, NORAD and ADC analyzed Type 2 Operations Buildings. NORAD determined that they were able to survive blast damage, but would require upgrading for radiation protection. For BUIC, ADC added "shielding" for all parts of the finished command post where the mission required constant attendance. The insertion of proposed computer equipment in the Type 2 buildings further necessitated a physical addition to the structures, although the new equipment was much smaller than that of SAGE. ADC looked at energy needs too and built independent power plants on sites where they did not already exist. Both communications and power functions were on a 24-hour alert status. ADC upgraded power plants with radiation shielding to support its alert role.[52] SAGE was still achieving its full buildout while BUIC was under consideration—and yet, ADC took SAGE off line at selected locations almost immediately when the command turned to BUIC. By 1960, 13 SAGE centers were operational. By 1961, 20 SAGE centers had come on line and by the end of 1962, all 23 were completed. The very last SAGE Direction Center to come on line was in Sioux City, Iowa, in December 1962. Yet, the very next year—1963—SAGE was operational at only 16 locations, with BUIC functional at 27 sites.

While ADC was in the initial stages of lobbying for what would become BUIC, NORAD also stepped into the picture with its own ideas for a network of air defense command posts to back up SAGE. NORAD's plan for a system of command posts directly mirrored that of ADC's BUIC program, and along with ADC sought to adapt selected Type 2 Operations Buildings for this purpose. The two agencies, in essence, were competing for the same physical resource, with very similar goals. This resulted in yet another name for air defense command posts: NORAD Automated Control Centers (NACCs) or NORAD Control Centers (NCCs).[53] Many Air Force documents use the term NCC interchangeably with that of BUIC, but the actual situation is more complicated. NORAD had first suggested its network in spring 1960. NORAD and ADC together formally proposed a backup network to Headquarters Air Force in early April 1961. Headquarters Air Force gave its approval in mid-June. By this date, NORAD was already using a small number of Type 2 Operations Buildings as NCCs. In July 1961, NORAD desired a system that would appropriate 70 of the 85 AC&W radar stations as NCCs—requesting "automation" of the back-up network, with each command post equipped with small, solid-state computers and display consoles. Of the 70 proposed NCCs, 24 were also to function as Master Control Centers responsible for the scrambling of manned interceptor aircraft and for actions by Nike missile squadrons. In contrast in September 1961, ADC's scheme for a back-up network called for 29 computerized command posts. The argument continued over the number of command posts, with figures of 70 (NORAD), 34 (the Department of Defense), and 29 (ADC) under consideration. The military agencies finally agreed on 34 NCCs in the continental United States and Canada. Each NCC was to have no more than five radar stations subordinate to it. All NCCs were to be no closer than 15 miles to a high-profile Soviet target. NCC sites were to have the best available radar coverage for an area. The proximity to FIS on alert was a further consideration. The Electronic Systems Division at Hanscom Air Force Base had the role of site selection for the NCCs. The division also evaluated each location's potential for survivability in nuclear war, additionally responsible for suggesting the numbers and locations of Canadian NCCs. The final numbers for ADC's BUIC remained unsettled, as did its relationship to the NORAD program. For a brief period at the outset of the 1960s, AFSC (through the Electronic Systems Division) and ADC moved on parallel tracks toward an air defense back-up network.[54]

ADC did activate its BUIC program, and NORAD's NCCs were generally streamlined into it to create a single back-up system. As was true for SAGE, ADC brought BUIC on line in stages, as BUIC I, BUIC II, and BUIC III. Multiple planning scenarios characterized the program between 1960 and its final buildout in 1968. BUIC I was manual (without the inserted computers). This first phase of the program was operational by the end of 1963 at the 25 former AC&W radar stations[55] (Plate 87). BUIC was still only tentative as of 1962, and BUIC I, NCCs, and manual SAGE centers had complex overlapping functions in some locations. BUIC I locations, from east to west, were: Watertown and Saratoga Springs, New York; Palermo, New Jersey; Cape Charles, Virginia; Tyndall Air Force Base and Key West, Florida; England Air Force Base, Louisiana; Rockville, Indiana; Port Austin, Finland, and Calumet, Michigan; Finley, North Dakota; Miles City and Havre, Montana; Olathe, Kansas; Tinker Air Force Base, Oklahoma; Lackland Air Force Base, Texas; Las Cruces, New Mexico; Winnemucca, Nevada; Luke and Williams Air Force Bases, Arizona; Boron and Point Arena, California; Keno, Oregon; and, Othello and Makah, Washington. ADC apparently decided to renovate the Type 2 Operations Buildings for both BUIC I and BUIC II (although this is not fully verified): there were no distinctions between the two systems, except the receipt of solid-state computers. Construction for BUIC II was underway from 1962 into 1965. The cost per site for BUIC I and BUIC II was about $100,000, with most funds needed for the radiological shielding. ADC added two-foot thick, reinforced concrete "fallout protection" walls encasing the Type 2 building, which created an air space of about four to six feet between the outer and inner (original) structure. Additionally, ADC removed the innermost four-inch concrete-block wall surrounding the operations (war) room in the Type 2 building and replaced it with a continuous metal RF (radiation field) shield. The command also raised the floor in the operations room, laid the metal radiation

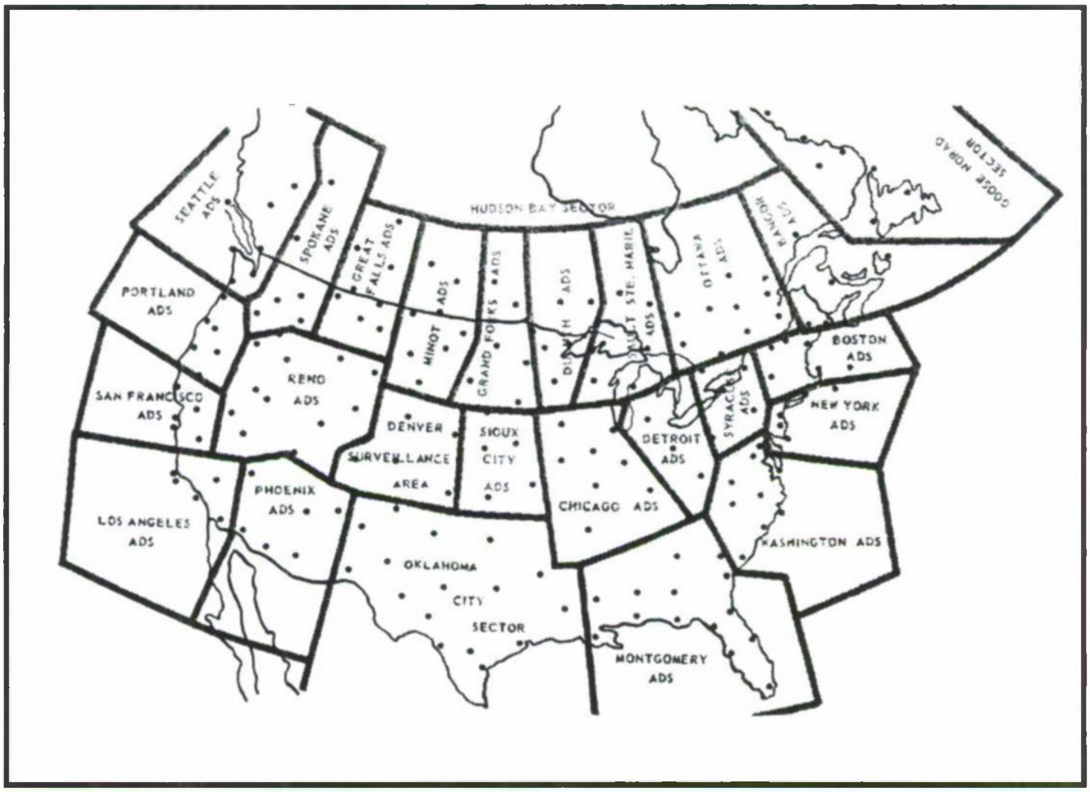

Plate 87: AC&W Radar System. Eighty-five radar stations in the continental United States, Canadian radar stations, offshore radar picket ships and Texas Towers, and gap-filler radars, May 1963. Approximate coverage was 177 facilities, with 27 of the original AC&W radar stations adapted for BUIC I. In *Air Force Civil Engineer*, May 1963.

shield over the original concrete floor, poured another two inches of concrete above the shield, and created an air space of one foot, three inches through the placement of small columns and a false floor above. The period of 1964-1965 was transitional, with both BUIC I and II command posts operational, and with SAGE downsizing to 15 sites on line.

BUIC II followed BUIC I. The RADC had the responsibility of developing the specifications for BUIC II's computer. The center worked with the Mitre Corporation at Hanscom Air Force Base and contracted with Burroughs to build the unit. The BUIC II computer was to be capable of managing data from a maximum of five radar stations, "continually observe at least 40 target tracks," and "control at least 10 simultaneous interception actions."[56] ADC planned for about half of the BUIC I manual command posts to transition to ones upgraded for BUIC II, including those of Watertown and Saratoga Springs, New York; Palermo, New Jersey; Cape Charles, Virginia; Tyndall Air Force Base, Florida; Rockville, Indiana; Port Austin and Calumet, Michigan; Finley, North Dakota; Miles City and Havre, Montana; Olathe, Kansas; Boron and Point Arena, California; and, Othello and Makah, Washington. These BUIC II command posts functioned as Master Control Centers. Planned renovation of Type 2 Operations Buildings at AC&W radar sites that had not operated under BUIC I—to additionally serve as Master Control Centers—included work at St. Margarets, New Brunswick; Santerre, Quebec; Finland, Minnesota; and, Mt. Hebo, Oregon. The 20 programmed Master Control Centers were to be the primary BUIC II network, with the 14 remaining command posts to be subordinate. The latter group were alternate master sites when required by circumstance. ADC

intended the second-tier BUIC II locations as those of Charleston, Maine; Benton, Pennsylvania; North Truro, Massachusetts; Montauk, New York; Fort Fisher, North Carolina; Jacksonville Naval Air Station, Florida; Bellefontaine, Ohio (Plate 88); Lowther, Ontario; Baudette, Minnesota; Fortuna, North Dakota; Beausejour, Manitoba; Almaden and Mount Laguna, California; and, Naselle, Washington. ADC modified Type 2 Operations Buildings at all BUIC II sites, with their air defense mission essentially interchangeable with one another.

Some of the BUIC command posts were short-lived in their air defense role. By late 1965, ADC committed to reorient the entire BUIC II network to yet a third version of the back-up system, BUIC III. At this date, BUIC II was just under construction.[57] The air defense program was highly complex and always fluid from its earliest years in late World War II through the end of the Cold War. The first four BUIC II command posts were those at North Truro, Massachusetts; Palermo, New Jersey; Port Austin, Michigan; and, Tyndall Air Force Base. Tyndall served as a training site. During 1966, beginning in January, BUIC II became operational at Calumet, Michigan; Cape Charles, Virginia; Fortuna, North Dakota; Blaine, Washington; Charleston, South Carolina; Keno, Oregon; Havre, Montana; Finland, Michigan; Mount Laguna, California; and, Fallon, Nevada (at the Naval Air Station). Fallon was the final BUIC II command post, operational in April 1966. As of mid-1966, 13 SAGE command posts remained on line, augmented by the 14 dispersed BUIC II stations. Construction was underway for BUIC III. As built and operational, BUIC III included a mix of the originally planned Master Control Centers and subordinate sites (Plate 89).

ADC anticipated full buildout for BUIC III at 30 to 31 converted AC&W radar sites. Similar to BUIC II, the initial BUIC III command posts were at North Truro, Massachusetts; Fort Fisher Air Force Station, North Carolina; and, Tyndall Air Force Base, Florida. The training site for the BUIC program, at Tyndall, served continuously in BUIC I, II, and III. Also of note was the command post

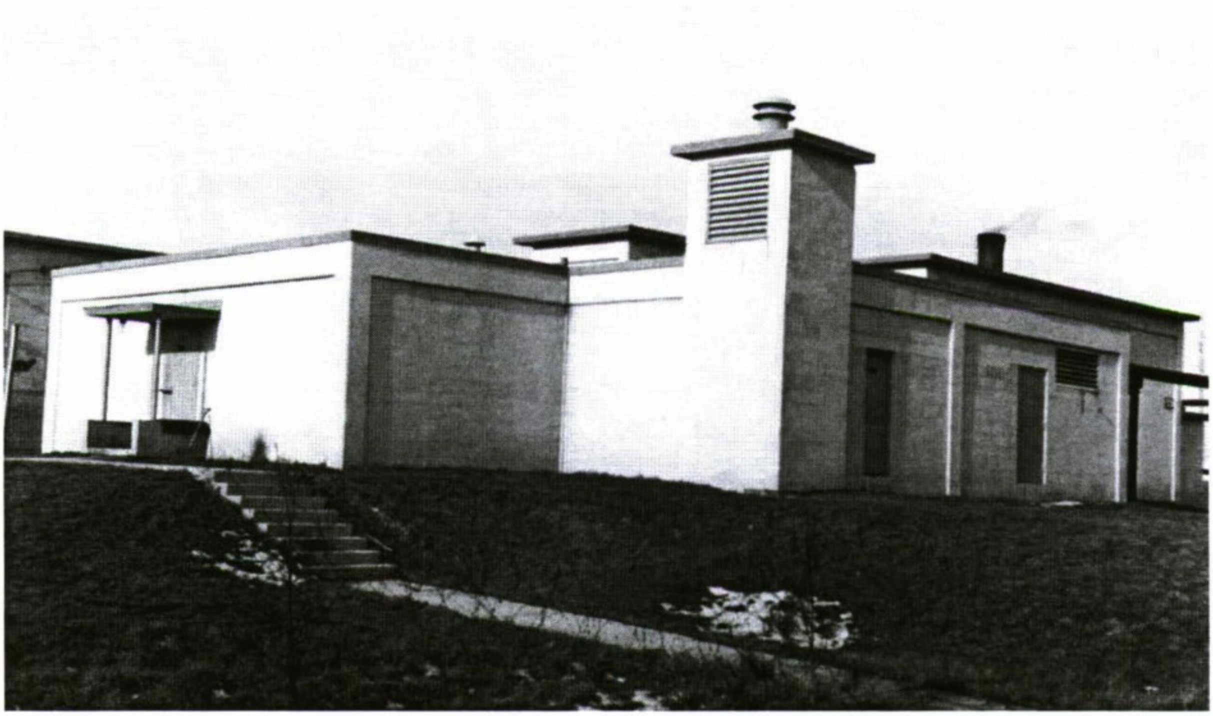

Plate 88: Type 2 Operations Building, AC&W Station, Bellefontaine, Ohio, January 1953. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

at North Truro. This station had played a critical R&D role from the early 1950s forward, functioning as an experimental ADDC for coordinated efforts with the Lincoln Laboratory at Hanscom Air Force Base. As of December 1966, ADC actively planned for 17 BUIC III command posts, with construction estimated at $335,000 per site and staggered into fiscal year (FY) 1968 at four to five installations per year.[58] In addition to the posts at North Truro, Fort Fisher, and Tyndall, ADC planned ones at Port Austin, Michigan; Havre, Montana; Keno, Oregon; Othello, Washington; Baudette, Minnesota; Mount Laguna, California; Palermo, New Jersey; Fallon, Nevada; Cape Charles, Virginia; Calumet, Michigan; Charleston Air Force Station, South Carolina; Fortuna, North Dakota; Blaine, Washington; and, Finland, Michigan (Plate 90). ADC also unsuccessfully argued for a BUIC III command post at Waverly, Iowa, as well as planning for two BUIC III locations in northeastern Canada. BUIC III was operational in 1969 and came on line into 1970. Like its predecessors, BUIC III stopped short of the anticipated buildout, at 12 command posts. For BUIC III, ADC added a distinctive three-room structure to selected Type 2 Operations Buildings that the command had previously modified for BUIC I or BUIC II. The addition directly abutted one outer wall, with the new space configured for a further upgraded war room and bracketing communications equipment rooms. The space created by the fallout protection wall encasing the Type 2 Operations Building, when augmented through the BUIC III room additions, approximately doubled the size of the original 1949 structure.

The BUIC I, II, and III air defense command and control network was never fully satisfactory, but was essential throughout the 1960s. While BUIC went in place, Electronic Systems Division at Hanscom continued to study questions of command post survivability. Even as ideas shifted from BUIC I through BUIC III, other plans came and went. One suggestion had been to mount the Burroughs computer equipment on vans and reconfigure each of the BUIC NCCs as a cluster of three sites about 25 miles apart. The computer for each NCC was to move on a random schedule between the locations, thus creating many more potential targets for the Soviet Union. The idea was very similar to those of Multiple Aim Point (MAP) basing and Multiple Protective Shelters (MPS) for the MX missile during the mid-to-late 1970s, and for the Peacekeeper missile in a Rail Garrison configuration at the end of the Cold War. NORAD's name for the mobile NCC was the Transportable Automated Control Environment (TRACE), a program jointly studied by Electronic Systems Division and the Mitre Corporation. TRACE suggested 38 NCC clusters of three as of late 1962, with this unbuilt program intended not just to back up SAGE but to fully replace it. At the end of 1962, ADC rejected TRACE and moved toward yet another air defense system—an "airborne BUIC." Work went forward for an airborne command post network based on earlier exploratory analyses and the Airborne Early Warning and Control (AEW&C) radar surveillance aircraft developed simultaneously with SAGE. ADC had initiated the AEW&C system with a provisional unit, the 4701st AEW&C Wing, at McClellan Air Force Base in California in October 1953. The command had followed it the next year with the 551st AEW&C Wing at Otis Air Force Base on Cape Cod (again, coordinated with SAGE). In 1955, the 552nd AEW&C Wing at McClellan expanded airborne surveillance.[59] The Air Force named the airborne BUIC the Airborne Surveillance and Control System (ASACS) in autumn 1962.[60] TAC managed the final program, the Airborne Warning and Control (AWAC) network, operational as of the middle 1970s. The AWAC system was a direct follow-on to AEW&C.

The SAGE and BUIC air defense networks continued to overlap for a number of years. As of 1970, SAGE dropped to six centers with BUIC III at 12. SAGE included two combined Combat-and-Direction Centers at Syracuse Air Force Station in New York and at McChord Air Force Base in Washington; the hardened Direction Center in North Bay, Ontario; and, three Direction Centers dispersed across the continental United States at Fort Lee, Virginia; Malmstrom Air Force Base, Montana; and, Luke Air Force Base, Arizona. In 1974, BUIC III dropped to only one operational location. SAGE continued to sustain its final six command posts into January 1984, when the Air

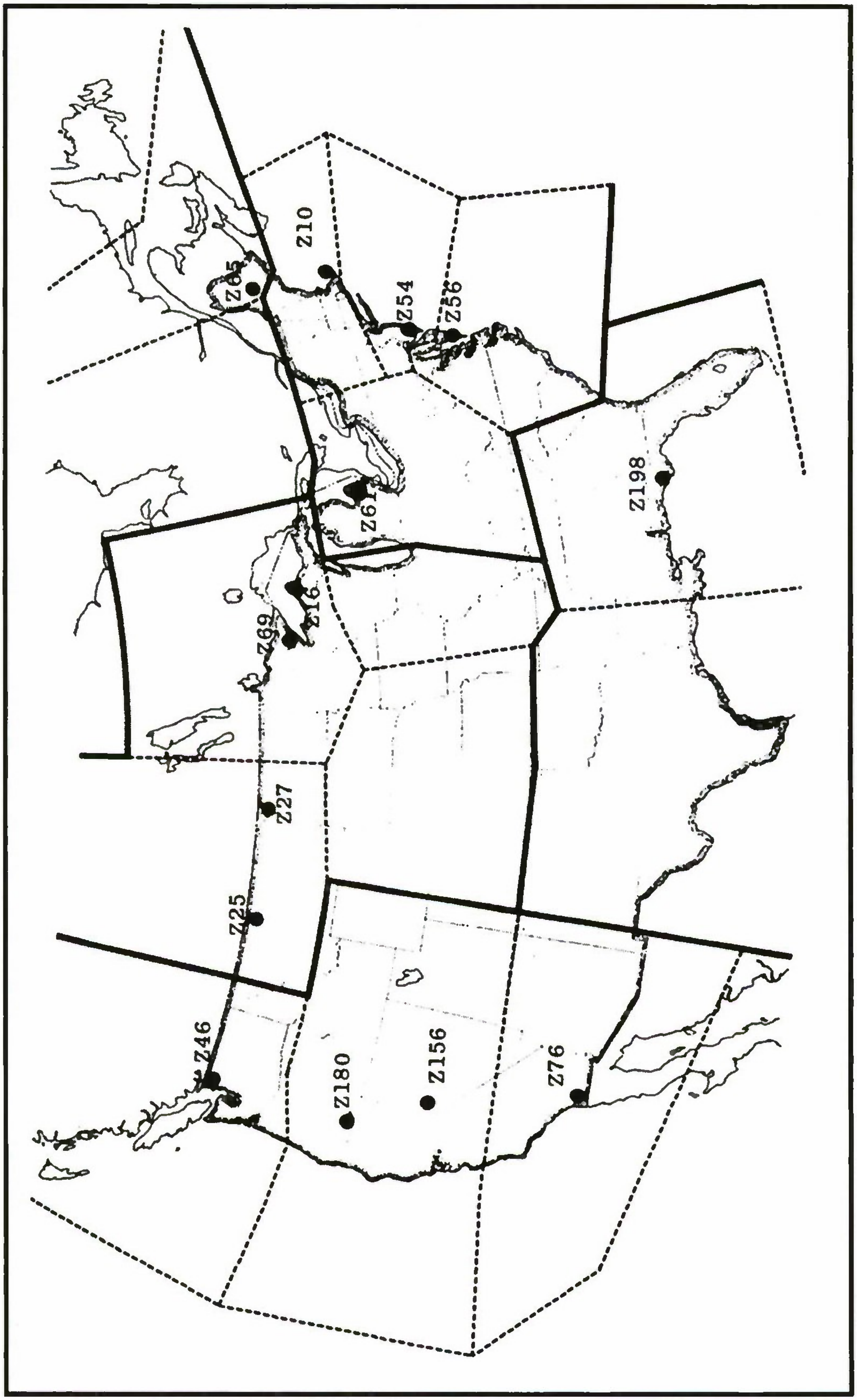

Plate 89: BUIC II in June 1966. In *History of the Air Defense Command January – June 1966*, volume 1.

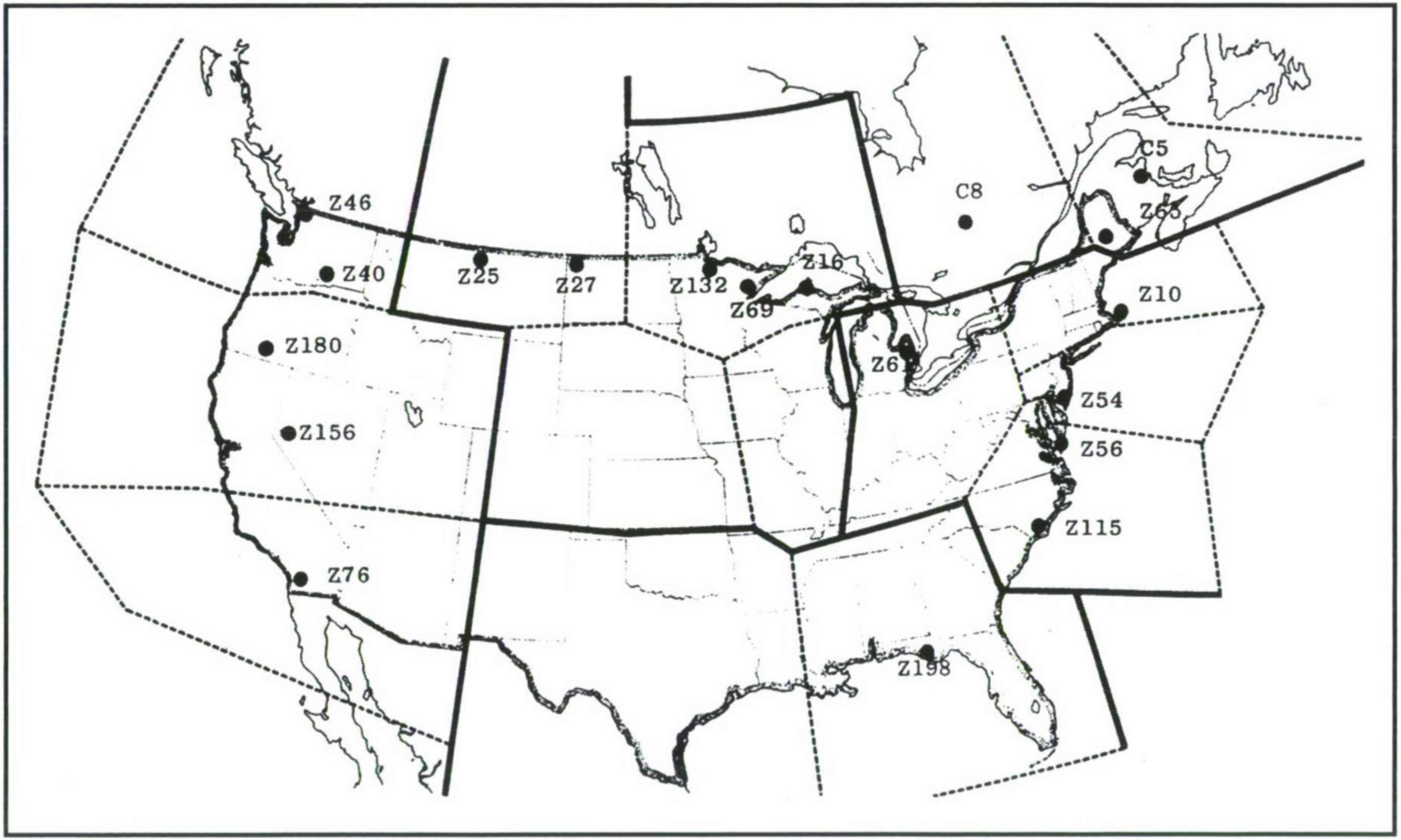

Plate 90: Planned BUIC III configuration, June 1966. (ADC built only 12 of the centers shown here.) In *History of the Air Defense Command January – June 1966*, volume 1.

Force fully deactivated the system. The last BUIC III site operated at least into 1981, with its deactivation date not confirmed. The final Cold War air defense command and control network replacing SAGE and BUIC III was the Joint (United States – Canadian) Surveillance System (JSS). In 1984, the JSS went on line at seven locations, with four in the continental United States (at March, McChord, Griffiss, and Tyndall Air Force Bases), and the remainder in Alaska (at Elmendorf Air Force Base), Hawaii, and Canada (at North Bay, Ontario). The Air Force also applied a new nomenclature for the JSS command posts, that of Region Operations Control Center (ROCC)—a name that strongly recalled the Region Control Center of World War II (the alternate titling of the Fighter Control Center).[61] The approach to infrastructure varied. At McChord, the choice was to completely renovate the active combined SAGE Combat-and-Direction Center. At the opposite end of the spectrum, the Air Force elected to abandon its operations in the combined SAGE Combat-and-Direction Center at Syracuse Air Force Station by moving the ROCC to Griffiss Air Force Base to the east and erecting entirely new infrastructure (Plates 91-92).[62]

Command Posts on Air Force Materiel Command Installations

Air defense command posts at AFMC installations in 2003 are numerous and varied, spanning the program from its earliest iterations to those at the end of the Cold War. Both Air Materiel Command, through its civil engineering role for the Air Force during the late 1940s, and ARDC / AFSC, through its responsibilities for radar, computer, and electronic communications R&D, were vital in decisions for the ADC network. For the first R&D efforts, the Watson Laboratories and the RADC worked on improving configurations for the war room in the ADCC and ADDC of the late 1940s and early 1950s. The RADC also erected an experimental operations room at Griffiss, using a prefabricated steel building for that purpose in 1951-1952. The ADDC at North Truro, on Cape Cod, also served as an experimental facility as a subinstallation of Hanscom (in a Type 2 Operations Building). ADCCs on ARDC / AFSC and Air Materiel Command / Air Force Logistics Command (AFLC) installations included ones at Griffiss (at its subinstallation of Hancock Field, Syracuse Air Force Station); Wright-Patterson Air Force Base; Tinker Air Force Base (at a subinstallation within one mile of the base); Kirtland Air Force Base; and, Norton Air Force Base. A temporary ADCC existed at Fort MacArthur, near Los Angeles, operating as a GCI station thereafter. Fort MacArthur would become a subinstallation to Los Angeles Air Force Base near the end of the Cold War. The probability of ARDC / AFSC and Air Materiel Command / AFLC installations having had responsibility for one or more off-site ADDCs is very high, and all of today's AFMC installations would have had some jurisdiction for at least one AC&W radar station. The AC&W radar at Bellefontaine, Ohio, is an example of the latter that was subsumed under Wright-Patterson Air Force Base (see Plate 88).

Activities across ARDC / AFSC and Air Materiel Command / AFLC that supported the successive networks of air defense command posts were numerous. For SAGE, MIT's Lincoln Laboratory coordinated early experiments at Hanscom for the Experimental SAGE Sector. Testing for Bomarc, the missile system built for SAGE, took place at Eglin Air Force Base, and included the evaluation of five types of launch shelters as well as missile crew training for the operational launch complexes. The radar surveillance aircraft (EC-121s) stationed at McClellan Air Force Base from 1953 to 1976 also coordinated with SAGE. Operational SAGE Combat and Direction Centers were affiliated with Griffiss (at Syracuse, one of three combined Combat-and-Direction Centers nationwide), and constructed on Norton Air Force Base. SAGE Combat and Direction Centers were planned but unbuilt at Kirtland and Tinker Air Force Bases in New Mexico and Oklahoma, and a Direction Center was programmed for Robins Air Force Base in Georgia (also unbuilt). The Type 4 Operations Buildings that had functioned as ADCCs at Kirtland and Tinker also served as manual SAGE centers during the early 1960s. And from SAGE onward, technical engineering studies for nuclear-hardened command posts in Europe became part of the mission of the Civil Engineering Branch within the AFWL at Kirtland Air Force Base.

Plate 91: ROCC, Griffiss Air Force Base, ca.1982. Courtesy of the History Office, Rome Research Site, AFRL.

Plate 92: Operations room, ROCC, Griffiss Air Force Base, ca.1982. Courtesy of the History Office, Rome Research Site, AFRL.

Once SAGE was fully on line, the air defense system was much more complicated. The Air Force reused Type 2 Operations Buildings at selected AC&W radar stations as BUIC I, II, and / or III command posts during the 1963-1981 period. For BUIC I, AC&W radar stations at Watertown, New York, and at Atolia, California, were subinstallations of Griffiss and Edwards Air Force Bases, respectively. The renovated Type 2 Operations Building at the AC&W radar site adjacent to Tinker was also a part of the BUIC I network, co-sited with an ADCC that contemporaneously served as a manual SAGE center. For BUIC II and III, the AC&W radar site at North Truro on Cape Cod, reported first to Otis Air Force Base and then to Hanscom. North Truro was perhaps the most important AC&W radar site of them all. It functioned in multiple roles over time from 1950 until the end of the Cold War and was consistently linked with R&D at the Hanscom laboratories. The "airborne BUIC" supplementing SAGE and BUIC III included the 552nd AWAC Wing of E3-As stationed at Tinker as of July 1976. The 552nd AWAC Wing was the continuation of the 552nd AEW&C Wing stationed at McClellan for the preceding 20 years. Finally, when the JSS replaced SAGE and BUIC III in 1984, one of the network's four ROCCs in the continental United States was built at Griffiss. This facility was collocated with the Rome Laboratories and is active today.

The Extended Mission at Tinker Air Force Base

An air defense station of particular note sat within a mile of Tinker Air Force Base as a subinstallation. As of August 1951, an ADCC and ADDC operated in permanent Type 4 and Type 2 Operations Buildings on a low hilltop site, supported by a Type 3 Operations Building (as an administrative unit), power plant, radar transmitting and receiving towers, recreation and maintenance buildings, and a group of eleven 32-man bachelors' dormitories. The Tinker subinstallation was alternately known as Area D (Plate 93). It combined the mission of the 546th AC&W radar squadron and that of command and control for the 33rd Air Division (Defense). Area D was an unusually complete air defense installation of the early Cold War, independent and segregated. ADC adapted the 1949 Holabird, Root & Burgee designs not just for the subinstallation's technical operations, but also for its support buildings. Initiation of construction for the command post in March 1950 was among the earliest for the country. The air defense units operated for about six months in World War II temporary quarters on Tinker proper while permanent buildings were under construction, the typical situation for many of the Air Divisions (Defense) during 1949-1951. The grouping of dormitories and officers quarters at Area D suggested a small cantonment for about 375 men.[63] The support buildings were all woodframe with cement-asbestos exterior shingling, common construction for the early 1950s and linked in materials, design, and layout to the Army 700- and 800-series temporary construction of World War II.[64] Holabird, Root & Burgee had designed cantonments, as well as experimental barracks, for Army camps during World War II. Yet making this choice again for the air defense stations of 1949-1951 is interesting. While the support cantonment exhibited no innovation, the technical buildings strongly reflected future war needs in their proto-hardened construction.

Area D at Tinker managed a changing air defense sector as the ADCCs and the system's radar stations came on line. ADC continued to refine its mission and changed air defense sector boundaries as its facilities became operational. In July 1951, the 33rd Air Division (Defense) controlled one of the two largest geographic areas nationwide. Both areas were within the jurisdiction of the Central Air Defense Force, with the initial conception that the interior land mass was the least threatened region on the continent. The 33rd Air Division (Defense) managed the states of Oklahoma, Texas, Louisiana, and Arkansas, and additionally had responsibility for about half of Kansas, Missouri, and Mississippi, as well as small portions of Tennessee and Illinois (see Plate 76). By February 1952, ADC refined the air defense sector of the 33rd Air Division (Defense) to include five complete states (Oklahoma, Louisiana, Arkansas, Missouri, and Kansas), plus most of Texas and part of Illinois (see Plate 77). ADC sustained this basic air defense sector under the 33rd Air Division (Defense) into

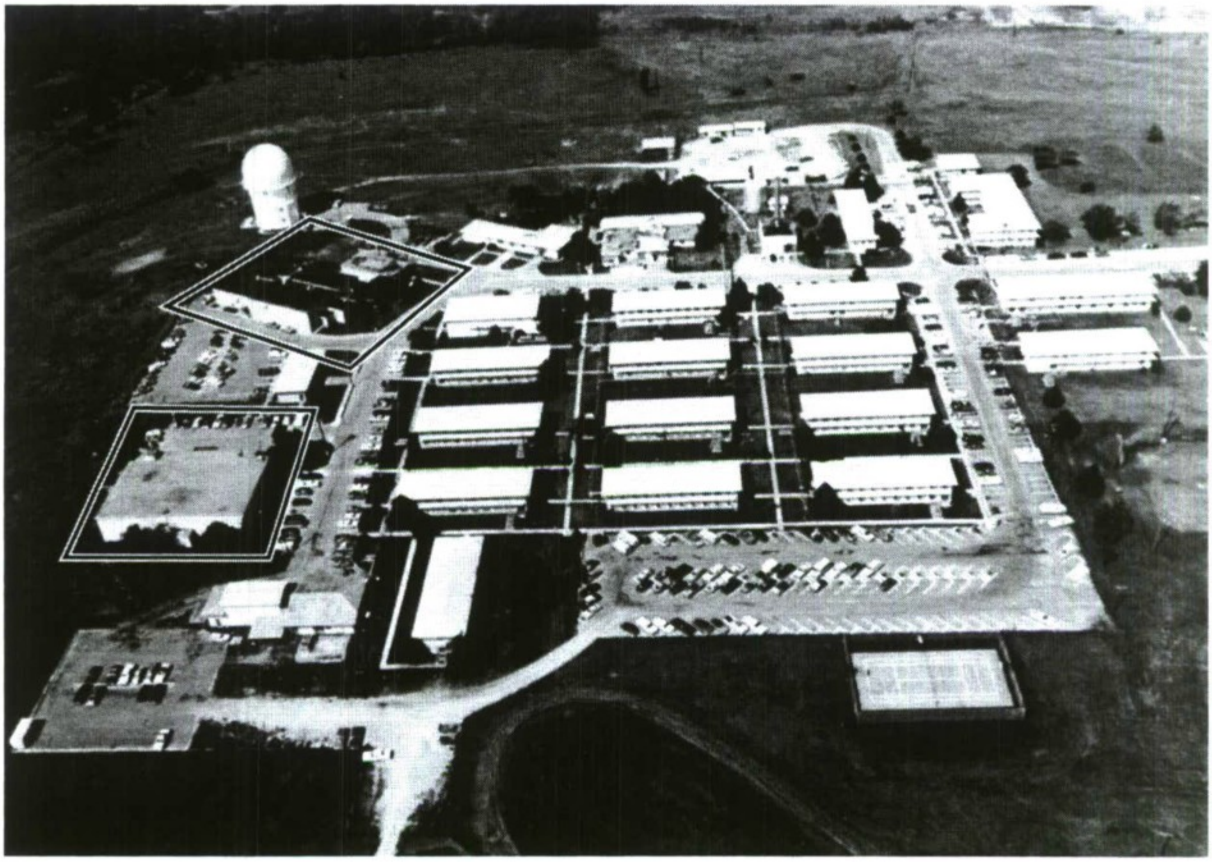

Plate 93: Area D, Tinker Air Force Base. Type 4 Operations Building, middleground left. Type 2 Operations Building, background left. Undated photograph. Courtesy of the History Office, Tinker Air Force Base.

1955, at which time 4,500 officers, airmen, and civilians worked for the division. As of December 1953, the 746th AC&W replaced the 546th AC&W at Area D, but radar operations were continuous. Units subsumed within the 33rd Air Division (Defense) included 14 AC&W radar stations, two FIS alert units, one ground observer squadron with 11 detachments, and one fighter group.[65] In late July 1955, with the activation of the 20th Air Division (Defense) at Grandview (Richards-Gebaur) Air Force Base in Kansas City, the air defense responsibilities of the 33rd Air Division (Defense) contracted, with the release of six AC&W stations, one FIS, five ground observer detachments, and the fighter group. Simultaneously, the 33rd Air Division (Defense) gained two AC&W radar stations, sustaining a total of 10 at mid-decade—nearly one-eighth of the total in the continental United States and Alaska.[66]

A number of changes for the ADCC at Tinker present a small case study of air defense advancements also occurring at most other ADC command posts. Two important changes to the war room in late 1955 included a switch from a horizontal plotting board to a vertical plexiglass one, and a redesign of the balcony.[67] The vertical plotting board was just one of many air defense achievements for which ARDC was directly responsible. The RADC developed and tested plotting boards to devise ones evermore accurate and efficient for tracking aircraft within air defense sectors. At Tinker, the first major alterations to the war room had occurred in October 1952, when ADC had installed partition walls with glass panels along the side dais platforms and in front of the demountable wooden balcony at the rear of the war room.[68] In 1955, ADC redesigned the dais arrangement of the ADCC war room

a second time.[69] In November 1954, ADC added an Alert Warning Memory Box Control Panel, again developed at the RADC. Toggle switches covered conditions "red," "yellow," and "white" for the 33rd Air Division (Defense), and also for the air defense sectors of the 29th, 30th, 32nd, 34th, and 35th.[70] The air defense sectors of the 34th (with its ADCC at Kirtland in New Mexico) and the 35th (an ADCC at Dobbins in Georgia) neighbored the 33rd, but those of the 29th, 30th and 32nd did not. The color-coded toggles likely paralleled those in use by SAC in the later 1950s. For SAC, red indicated imminent attack, yellow a surface evacuation, and white quiet conditions.[71] These kinds of changes continued steadily in 1956, with the installation of "direct reading clocks" in all AC&W operations rooms. ADC shipped obsolete plotting boards from the ADDCs to the civilian Filter Centers.[72] During the late 1950s, ADC was gearing up for substantial change at Tinker. As of 1957-1958, the command added rooms behind the vertical plotting board and also enlarged the power plant.[73]

By autumn 1959, ADC instituted major shifts in the structuring of its air defense for the region. Effective as of January 1960, ADC redesignated the 33rd Air Division (Defense) as the 33rd Air Division (SAGE), with the command relocating the 33rd Air Division (SAGE) from Tinker to Richards-Gebaur Air Force Base in Kansas City. Richards-Gebaur's ADCC previously served the 20th Air Division (Defense), coming on line as a stopgap while SAGE finished its buildout. It had responsibility for geographic territory that had originally been under Tinker's ADCC.[74] At the same time, ADC assigned the ADCC at Tinker to the 32nd Air Division (SAGE). Air division numbering, which continued during SAGE, always referenced the Air Division to which SAGE centers reported. It did not always carry forward from the preexisting ADCC and ADDC network. Thus, the "32nd," an air defense sector encompassing upper New England down to New York in the early and middle 1950s, shifted to the southeast United States by 1958 and became yet another part of the country for SAGE.[75] Tinker's ADCC became a manual SAGE Direction Center for the 32nd Air Division as of January 1960. ADC planned for the Tinker command post to take over the command and control function from the ADCC previously managing the 32nd Air Division (Defense), that at Dobbins Air Force Base in Georgia, by the end of the year. Under SAGE, the 32nd Air Division physically expanded westwards to include the land across the Gulf Coast to Texas and Oklahoma. During 1960, the command post's formal title was the Oklahoma City Air Defense Sector (Manual), with responsibility for the four states of Texas, Oklahoma, Arkansas, and Louisiana. In 1961, the sector's jurisdiction added Mississippi, Alabama, Georgia, and Florida, as well as part of New Mexico.

The 32nd's air defense jurisdiction from Georgia to New Mexico in 1961 also pointed to the fundamental problem of bringing SAGE on line in a timely manner. ADC had to select its command post for the 32nd Air Division from three possibilities: the existing ADCCs at Tinker and Dobbins (built for the first-generation air defense network and therefore possible candidates for manual SAGE centers), or the SAGE Direction Center at Gunter Air Force Base in Montgomery, Alabama. The command chose to assign the Montgomery Direction Center a special mission: to train personnel, test SAGE links to the Bomarc guided missile program, and evaluate the frequency diversity radar—with the prototype missiles and radars placed at Eglin Air Force Base in the Florida panhandle. This mission consumed a portion of the Direction Center's time, which in turn elevated the importance of its associated manual center. The 32nd Air Division next moved its headquarters to Tinker and started to close the ADCC at Dobbins. ADC simultaneously consolidated the Oklahoma and Albuquerque manual SAGE centers (in preexisting ADCCs) as a single manual area (that of Oklahoma City) which supported the SAGE Direction Center in Montgomery. While these events took place, the SAGE Direction Center at Montgomery continued transitioning toward an operational air defense responsibility.[76] Physical modifications to accommodate the SAGE mission in the Type 4 Operations Building at Tinker occurred as of January 1961,[77] focused on room reconfiguration, increased electrical capacity, and installation of an automatic display system. Manual SAGE centers did not acquire the IBM mainframe computers, but did support enhanced communications and data needs.

While the move from Dobbins to Tinker was in progress, political events festered in the Southeast that would affect the air defense command post at Tinker. On 3 January 1961, the Eisenhower administration broke off diplomatic relations with Cuba—the administration's final foreign policy act. ADC interpreted the situation as a threat to southern Florida where air defenses were weak. Continental Air Defense Command (CONAD), a joint Air Force, Army and Navy command created in 1954 foreshadowing NORAD, instituted a plan for augmenting air defense in Florida known as Southern Tip.[78] While CONAD cobbled together fighter and radar squadrons during the growing emergency, the primary command and control for air defense operations was troubling. The SAGE Direction Center in Montgomery had "only a small portion of total computer time...available for normal air defense operations." Its main function continued to be support for the development of Bomarc, the frequency diversity radars, and advanced FIS links to SAGE. As partial compensation for the situation, ADC designated all available AC&W radar stations along the Florida-Alabama Gulf Coast as ADDCs, also beefing up FIS on area alert and borrowing radar picket ships from the 26th Air Division to the north. The command deployed mobile radar and communications equipment, and added Navy resources to the air defense program. In mid-April 1961, with the 32nd Air Division still operating from Dobbins in Georgia (but preparing to physically relocate to Tinker), ADC ran a suitability test of Southern Tip. Simultaneously, anti-Castro forces backed by the United States attempted and failed in an invasion of Cuba.

As of this date, buildup for a better and more permanent air defense of Florida accelerated, with the inclusion of more units as well as Nike-Hercules missile batteries, the Bomarc launchers at Eglin, and AEW&C aircraft. Gap-filler radars (up to 150 planned for the United States) were also under construction as of 1960 to augment the existing AC&W radar stations. These facilities, however, were just going in. The 551st AEW&C Wing from Otis Air Force Base in Massachusetts manned an "on-call" AEW&C station in the Florida Straits as an interim measure, while the gap-filler radars remained pending. Not until late the nest year was the 551st AEW&C operational at McCoy Air Force Base in Orlando, joined by three aircraft deployed from the 552nd AEW&C at McClellan in California. The intent was to achieve "the integration of all forces in the Montgomery SAGE sector on an automated basis." Reality remained *ad hoc*, with the Gunter SAGE Direction Center on line 108 hours weekly for Southern Tip and 60 hours weekly to continue its test and training mission for Bomarc and the frequency diversity radars. During those 60 hours, the ADCC at Tyndall Air Force Base in Florida took over for Montgomery in a manual capacity. In August 1961, the 32nd Air Division formally moved its headquarters to Tinker during Southern Tip and set up the manual SAGE Direction Center in the Type 4 Operations Building in Area D.

Between activation of the manual SAGE center at Tinker and October 1962, air defense for the 32nd Air Division operated in a somewhat unusual manner. ADC formally designated the Type 4 Operations Building, built as an ADCC in 1950, as the 32nd Air Division SAGE Direction Center (Manual). Simultaneously its neighboring structure, the Type 2 Operations Building built as an ADDC for a collocated AC&W radar squadron formally became the 32nd NORAD Region Combat Center.[79] NORAD had established its own air defense sectors in 1960 that overlapped with ADC's division of the continental United States into SAGE areas. As a part of the process, NORAD had also introduced its command post, the NCC (see above).[80] By the end of 1961, eight regional NCCs existed in the United States, Alaska, and Canada.[81] As a NORAD NCC, the Type 2 Operations Building at Tinker additionally functioned as headquarters for the 32nd CONAD Region. During 1962, the SAGE Direction Center at Gunter in Montgomery, with its manual backup at the former ADDC at Tyndall, reported to Headquarters 32nd CONAD at Tinker.[82] The 32nd Air Division SAGE Direction Center (Manual) at Tinker functioned as a second backup to the automated center in Montgomery. The system as a whole was highly redundant, so that the American air defense network would remain operational and successful in its mission should nuclear war occur and selected command posts become casualties. Although ADC intended to fully shift air defense management for

the 32nd Air Division to the SAGE Direction Center at Gunter as of October 1962, the program continued to run behind. When the Cuban missile crisis occurred late that month, both the 32nd CONAD Region and the 32nd Air Division (SAGE) at Tinker Air Force Base found themselves to be recipients of key roles in the air defense of the Gulf Coast of the continental United States.

At the time of the Cuban missile crisis in the autumn of 1962, preparations for the effective air defense of southern Florida and the Gulf Coast still included command posts spread among a variety of stations, with multiple weapons systems—including armed FIS—reporting. As of the previous spring, the primary command post for immediate response to activities in Cuba was that established as a Control Center at Key West. It was in a Jamesway hutment[83] at the existing Naval Air Station, with an adjacent house trailer for the assigned commander. The Key West command post was known as CONAD Task Force 32 and also went by the code name Brownstone. When the United States went to DEFCON (Defense Condition) 3, the alert condition of October 22, it became apparent that the very limited facilities at Key West could not effectively manage the situation, and the SAGE Direction Center in Montgomery assumed responsibility for part of the immediate area (Miami). Air defense, reconnaissance, and air-sea aircraft created abnormally dense air traffic conditions, and coordination between ADC and SAC was especially difficult. Fighter squadrons did not have the appropriate means to identify SAC aircraft flying their own reconnaissance missions between the United States and Cuba, and thus FIS aircraft repeatedly locked-on to SAC planes as "unidentified." Air defense operations up the chain of command for the Cuban missile crisis were the responsibility of the headquarters for the 32nd CONAD Region, located at Tinker in the Type 2 Operations Building in Area D. The personnel of the 32nd Air Division (SAGE), working in the neighboring Type 4 Operations Building, assisted in the management effort.[84]

In October 1962, the entire network of air defense command posts relied upon control centers replacing one another should the need arise, from the highly sophisticated SAGE Direction Center at Gunter Air Force Base in Montgomery to the hastily assembled Jamesway hutment operation at the Key West Naval Air Station. Headquarters for the 32nd CONAD Region orchestrated the command post setup through a series of operational configurations that were contingent on the conditions at hand. In one scenario, a combined SAGE -and- manual operation relied on the SAGE Direction Center at Gunter in concert with backup from CONAD Control Centers at the Key West and Jacksonville Naval Air Stations. In a second scenario, with a failure of the SAGE Direction Center at Gunter, the ADDC at Tyndall Air Force Base would take over for the Gunter command post as its direct manual backup. If communications links to the SAGE Direction Center at Gunter were lost, yet other scenarios went into effect that shifted operational control to command posts in southernmost Florida. In one scenario, the radar station on Patrick Air Force Base was to operate as a manual Direction Center. The Montgomery NORAD Sector Air Defense Plan laid out the air defense directives of the 32nd CONAD Region.

As of the events of October 1962, Headquarters 32nd CONAD Region developed an Operations Plan for a possible conflict with Cuba.[85] Specifics assigned to CONAD all focused on air defense.

> CONAD participation will consist of supporting CINCLANT [Commander-in-Chief Atlantic Fleet] from CONUS [Continental United States] bases and providing information on movement of aircraft believed destined for Cuba.
>
> Conducts intercepts, diversion, and if prepared, destruction of suspected aircraft which fly within the coastal ADIZ [Air Defense Identification Zone] within range of CONAD Air Defense system.

The *32nd CONAD Region OPLAN 2-62* of 27 October 1962 further defined the roles of the 32nd CONAD Region, as well as the subordinate roles for the SAGE Direction Center at Gunter, the manual Control Centers, and the 32nd Air Division. Headquarters 32nd CONAD Region at Tinker was to "prevent aircraft en route to Cuba, which are believed to carry prohibited material, and operating in specific airspace designated by CINCONAD [Commander-in-Chief CONAD], from reaching their destination." "Prohibited materials" included

> armaments for air, sea, and land craft; surface-to-surface missiles; bomber and fighter aircraft; bombs, air-to-surface rockets and guided missiles; warheads for any of the above weapons systems; mechanical or electrical equipment to support or operate the above items; and any other items that hereafter may be designated by the Secretary of Defense.

The SAGE Direction Center at Gunter in Montgomery had most of the responsibility for computer-coordinated air defense, backed up by the manual Control Centers. The 32nd Air Division was, when requested, to "seize and secure aircraft landing at USAF ADC facilities." In short, not only was the 32nd CONAD Region to guard the United States from enemy attack, but also to prevent enemy aircraft from delivering weapons to Cuba through airspace within its jurisdiction. The latter task had larger implications than simple air defense, but stopped at strategic planning for invasion or insertion—the roles of SAC and TAC within the Air Force.

Day to day tasks during the crisis were numerous. Top Secret communications between Headquarters 32nd CONAD Region at Tinker, and command posts in Florida and Alabama, discussed items ranging from the procurement of separate telephone lines to the rules of engagement. The 32nd CONAD Region also set up liaisons between Air Force units in Florida, such as a "scramble and status telephone circuit" between the SAGE Direction Center at Gunter and the SAC Command Post, and a switchboard to maintain telephone contact between the TAC Command Post and all ADC units within the Montgomery Air Defense Sector. Direction of FIS alert during the Cuban crisis was yet another air defense duty of 32nd CONAD Region personnel working at Tinker. The 32nd CONAD Region managed fighter squadrons based at MacDill, McCoy, and Patrick Air Force Bases. The 32nd Air Division (SAGE) handled such matters as radar search deficiencies and other tasks as directed by Headquarters ADC and the 32nd CONAD Region. The 32nd Air Division (SAGE) deployed additional mobile search radars in the weeks leading up to the crisis, as well as requested upgraded permanent radars (an AN/FPS-20 to replace an AN/FPS-37 at Key West), with communications between Tinker, Headquarters ADC at Ent Air Force Base in Colorado, and the Florida-Alabama command posts.

As of 1963, reorganization of air defense responsibilities continued across the southern United States from New Mexico to Florida that affected activities at Tinker's Area D. Within the larger umbrella program for air defense, the Type 2 Operations Building at Tinker became a BUIC I command post. ADC upgraded the building (which had functioned as an ADDC, 1950-1960, and as an NCC, 1961-1962) with a fallout wall encasing the original structure and added radiation shielding. Tinker did not continue as a BUIC II or BUIC III command post as of 1966, but the 746th AC&W radar station (through which the BUIC I post functioned) was active into 1968. BUIC II and III ringed the continental United States along the East and West Coasts, as well as covering the United States-Canadian border (see Plates 89-90). ADC left the Gulf Coast and the border with Mexico unprotected from the Florida panhandle to San Diego. Also in 1963, the command downgraded the 32nd Air Division (SAGE) from division to sector status. The command post located in the Type 4 Operations Building in Area D subsequently reported to the 29th Air Division then headquartered at Richards-Gebaur Air Force Base in Kansas City.[86] Both the Type 2 and Type 4 command posts in Area D sustained lessened air defense roles within the overall network with the shift from BUIC I to BUIC II

and III, as well as a subordination to the 29th Air Division. Area D's command posts went into caretaker status under the jurisdiction of the 31st Air Division from spring 1966 to December 1969.[87]

As of 1970, Area D took on yet another life connected to Air Force air defense through the Ground Electronics Engineering Installation Agency (GEEIA), a subcommand of AFLC. The Area D command posts, as well as some of the site's ancillary structures, continued in this follow-on role through the end of the Cold War (still functioning in this role in 2000). GEEIA was an Air Force organization instituted in 1958 and managed under Air Materiel Command. GEEIA's mission was to develop and maintain the network of ground electronics that supported international strategic and air defenses of the Air Force. At its inception, GEEIA had the responsibility for the electronics systems for SAGE and the radars of the Distant Early Warning (DEW) line across Alaska and Canada. The GEEIA communications mission, only partially one of air defense, was complex, involving not just unusual logistics issues, but also ones of essential standardization across systems. GEEIA developed and made use of Air Force "corporate" knowledge about the links between such systems and was proficient in the engineering and maintenance needs of individual sites at very challenging physical locations that typically required upgrading over time. For nearly a decade, ARDC had relied on contractors—such as the MIT Lincoln Laboratory, IBM, Burroughs, Bell Telephone, and General Electric, among many others—to help develop the sophisticated systems of air defense (such as SAGE and its associated radars, communications links, and weapons systems). The individual components of SAGE, for example, were not particularly compatible with one another, which complicated military-mission and logistics issues once the overall system was on line. GEEIA's job was to take the electronics networks forward from their research, development, testing, and evaluation phase, into a sustainable, uniform Air Force usage. GEEIA maintained a strong logistics function, with the Rome depot at Griffiss assigned within Air Materiel Command (and subsequently AFLC) as of 1959 to be the direct manager for GEEIA. The GEEIA mission also raised the Rome depot to the level of an AMA once more, although Rome did not regain geographical responsibilities paralleling the other eight AMAs. GEEIA required depots across the United States for its mission. The initial decision was for three: Brookley in Alabama for the eastern United States; Tinker for the central area of the continent; and, McClellan in California for the West.[88]

While the main base at Tinker assumed a key role for GEEIA as of 1958-1959, the Area D enclave of command post buildings became the agency's administrative and technical work site a decade later. By May 1970, the official date of the mission's initiation in Area D, GEEIA's needs and official title at the former ADC command post was the Southern Communications Area (SCA). SCA represented a merger of two distinct, but related, entities: the Central Communications Region (the depot role of GEEIA for the central United States) and GEEIA's central administrative group (which was a subcommand of AFLC). SCA was one of six subcommands reporting to the Air Force Communications Command (AFCC) and thus became a tenant mission (as had been ADC) at Tinker rather than a subordinate unit of AFLC. SCA at Area D sustained its communications mission across the 18 states that defined the southern tier of the continental United States. The mission of SCA was very similar to that of the late 1950s GEEIA: "to engineer, install, operate, maintain, and manage a vast array of communications-electronics (C-E), navigational, and meteorological equipment and facilities in support of the Air Force and other government agencies." SCA personnel from Tinker worked on facilities within the United States, but also at stations in Alaska and the Panama Canal Zone, as well as on the eastern and western missile test ranges.[89] Both GEEIA and SCA were part of a complicated lineage of communications agencies, with multiple name changes over time.[90] In 1970, when the SCA mission arrived at Area D, the AFCC was headquartered at Richards-Gebaur, thus continuing a reporting relationship between the Tinker site and that Air Force base. AFCC reconfigured the SCA as its Engineering Installation Center (EIC) in mid-1981. The command assigned EIC the responsibility for all of its international engineering and installations units. As of

early 1983, EIC became the Engineering Installation Division—the final Cold War role of Area D at Tinker Air Force Base.

Fighter Alert

Fighter-interceptor squadrons on 24-hour alert (FIS) were strongly tied to the command and control mission across the continental United States.[91] FIS were yet another ADC (and later, TAC or ANG) tenant mission prominent at ARDC / AFSC and Air Materiel Command / AFLC installations. Like the numbers of supportive radar stations for ADC, the numbers of fighter squadrons on alert were high, with fluid and complex assignments at bases across the country. ADC and TAC also stationed FIS at non-Air Force installations such as Naval Air Stations, and through ANG at both Air Force bases and municipal airports. Each FIS tenant mission at an Air Force base maintained its own segregated area on the flightline, with an alert hangar, alert apron and ramp, maintenance and ready hangars (one or two, typically), ready crew dormitory, squadron operations building (if not combined with the crew dormitory), flight simulator, aircraft shelters (only at northern tier bases), electronics and calibration shelters (for SAGE-linked aircraft), and weapons checkout and storage facilities. Again, as for the radar stations and the command posts, multiple generations of FIS alert infrastructure existed to support the air defense mission. Each major type of structure at FIS alert sites had generational versions, with their construction at individual locations sometimes uneven. A first-generation alert hangar might easily coexist with third-generation weapons storage. Or, a second-generation alert hangar that replaced an earlier one at a base might function in tandem with original ready crew dormitories. The key infrastructure for a FIS alert area, that of the alert hangar, made the situation even more complicated. At the outset of the 1950s, ADC tried variants before settling into the two successive standard structures that followed. ADC command posts, from those of the ADCC of 1949-1958 through SAGE and BUIC I, II, and III into the early 1980s, scrambled fighter-interceptor aircraft when potentially threatening situations arose, during practice alerts, and for routine ferrying of Soviet aircraft down the coastal shores of the United States.

FIS alert clusters and command posts were integral to one another, but only at times were the two collocated. This situation was primarily a byproduct of the larger numbers of FIS than command posts. By 1952, 40 FIS were on alert in the United States. In that year, there were 11 ADCCs. Two years later, fighter-interceptors on alert had risen to 55 squadrons while command posts remained static. The year 1956 was the peak of FIS on alert in the continental United States, with 65 squadrons parked at Air Force bases across the country. (The figure of 65 does not include ANG FIS.) ADCCs numbered 16 and the transition to SAGE was imminent. Air defense policy began to reduce fighter alert thereafter, to 62 squadrons in 1959 and 44 in 1962-1963. The greatest number of FIS alert sites overlapping with command posts occurred in late 1962, when all 23 SAGE centers were on line. That particular confluence was somewhat ironic due to the timing of the Cuban missile crisis. A maximum combination of command posts and FIS should have been able to handle that situation. However, not only was the SAGE Direction Center at Gunter Air Force Base in Montgomery preoccupied with its test missions, alert FIS across the southeastern Gulf Coast were extremely weak. As was true for ADC command and control, 1962 was a time of intense transition for FIS weaponry, with many alert hangars requiring modification to accommodate the F-101B. The numbers of both operational FIS and ADC command posts steadily declined from the middle 1960s through the end of the Cold War. In 1967, 31 FIS were on alert in the United States, with 13 SAGE centers on line and 12 BUIC II. By 1970, FIS had shrunk to only 14, with six SAGE centers and 12 BUIC III. In 1980, FIS and SAGE both maintained only six sites each, with one BUIC III. Many bases possessed FIS infrastructure no longer active for alert that was typically used for completely unrelated functions. Perhaps the most striking situation, visually and historically, is the existence of a 1951 double-squadron Butler FIS alert hangar and a mid-1980s ROCC command post at the former Griffiss Air Force Base in Rome, New York.

Air defense employing fighter-interceptor aircraft was only tentative during the late 1940s and operated in makeshift circumstances at both Army Air Fields and municipal airports. The aircraft themselves were transitioning from propellers to jets, while runways were of short World War II types. Much of the air defense role for pursuit aircraft fell to ANG, with older planes assigned to that command. The fastest aircraft went to the Army Air Forces (and subsequently, the Air Force), with only the newest equipment featuring night and all-weather capabilities. Most runways were not the 7,000-foot minimum length required for fighter jets, although upgrading of runways was a priority in a number of places. While ANG argued over how to set up a reasonable air defense network, and while Air Materiel Command took steps toward future command and control, ADC—like other Air Force commands—was preoccupied with its basic organizational needs, including the training of pilots and ground crews for planes of the era ahead. By 1948, ADC parked alert aircraft at the end of designated runways at some installations, with alert crews living alongside their planes in ready shacks and trailers. The command called its first formal 24-hour, continuous alert in late March the same year, following the Soviet invasion of Czechoslovakia in February. Air defense concentrated on the Hanford atomic energy plant and the Boeing manufacturing sites in eastern and western Washington. Before 1948 ended, the Air Force changed the designation of fighter aircraft from "P" (pursuit) to "F" (fighter). Both international political events and rapidly improving fighter planes, as well as runways on which to land and take off, further stimulated progress in 1949.

The start of the Korean War in June 1950, however, was the event that shifted everything into high gear. FIS alert was the primary weapons system (manned and armed interceptor aircraft) that command posts scrambled into action. While the ADCC and ADDC network dated to 1948-1949, parallel efforts for FIS alert dated to 1951. Civil engineering attention to FIS infrastructure was also much less intense, with four designs for an alert hangar and with ancillary structures routine. During 1950, the Air Force expanded its FIS program, while President Truman federalized available ANG fighter squadrons to operate in an Air Force role. The first squadrons were ones that possessed adequate support infrastructure and were stationed in radar-covered areas. By the end of the year, the Air Force equipped four federalized ANG squadrons with modern F-80 and F-84 jet aircraft. Federalization became official in February 1951 for 15 ANG squadrons, with another six added the next month. Between January and March 1951, the Air Force Directorate of Installations turned to Mills & Petticord of Washington, D.C., for preliminary work toward the design of an alert hangar. As of April, the task of commissioning the specialized hangar became earnest, although the Directorate of Installations did not formalize the definitive layout standards for the accompanying alert apron until the outset of 1952. Between 1951 and 1954, ADC surveyed many municipal airport and Air Force locations for the placement or relocation of FIS for air defense. Multiple factors influenced decisions. Sometimes World War II runways were too short. In other cases, existing buildings offered short-cuts as supporting infrastructure. In still other situations, the immediate geography constrained plans or created such invisible frustrations as radar echoes. Particular urban areas could only offer saturated air space. ADC reviewed other military installations outside the Air Force, as well as reconsidered which parts of the continental United States necessitated the greatest concentration of 24-hour alert FIS.

Between April and September 1951, ADC evaluated variant designs for a FIS alert hangar. The hangars were of similar size and were all derived from prefabricated components. Each featured a small, centered alert crew quarters, with two fighter aircraft pockets flanking to the right and left for a single-squadron facility. (A relatively few double-squadron hangars had four aircraft pockets to each side of the alert crew quarters.) The four hangars adopted by the Air Force were a "standard" fighter alert hangar designed by Strobel & Salzman of New York, an "efficiency" model designed by Butler Manufacturing of Kansas City, an alternate to the Butler hangar designed by Luria Engineering of New York, and what was called "the Continental hangar." While the standard hangar went up in the greatest numbers nationwide, the Butler hangar is often found in priority locations of the early Cold

War. The Luria hangar appears to have been an aborted design. An article of the early 1950s in *Aviation Week* suggests that the Air Force erected it only three times.[92] The only known example of a Luria hangar is at Langley Air Force Base in Virginia. The Continental hangar, a simple, gable-roofed structure, typically without front and rear aircraft pocket doors, was usually the choice overseas. The maker for this hangar is not completely verified, but is likely Continental Steel Buildings Company. (Continental Steel of Los Angeles and International Steel of Evansville, Illinois, manufactured the two door types used for the Strobel & Salzman hangar. Luria was affiliated with Bethlehem Steel in Pennsylvania.) Butler hangars were bolted buildings, which the Air Force could, and did, move to accommodate lengthening runways. Unusual "split" clusters of ancillary infrastructure appear at installations where ADC relocated a Butler alert hangar. Kirtland Air Force Base is an excellent example of this phenomenon. FIS alert squadrons sometimes were present at an installation temporarily, yet could sustain a long-term relationship through an active assignment nearby. These "hidden" FIS were relatively common: Sioux City, Iowa, for Offutt Air Force Base; Presque Isle, Maine, for Loring Air Force Base; George Air Force Base, for Edwards. During the middle Cold War years, selected installations formalized this type of FIS linkage through an alert satellite detachment on base which was the case at George and Edwards.

Air defense FIS alerts achieved five-minute status for two to eight aircraft by December 1951, with squadrons maintaining another third of the aircraft on three-hour alert. ADC (and much more rarely, TAC) steadily erected the four types of first-generation FIS alert hangars between 1951 and 1956. The numbers of FIS and alert hangars are similar, but not identical. At some locations, a double squadron was on alert in one, eight-pocket hangar,[93] while replacement of a hangar with a newer version also confuses any tabulation of the infrastructure. There were approximately 51 FIS alert hangars actively in use for the air defense mission as of October 1957 in the continental United States and overseas, with 13 double-squadron hangars probable among this group. By December the same year, total FIS alert hangars is about 56, with the gain fully outside the continental United States. Buildout is estimated at 15 to 20 Butler hangars, 30 to 35 standard Strobel & Salzman hangars, three Luria hangars, and seven to 10 Continental hangars (to about 1960).[94] Occasionally, a single squadron expanded to double-squadron size. In a few cases, the alert crew quarters that were normally centered between flanking aircraft pocket pairs are found at the end of the hangar. When this occurred, the Air Force either added four more aircraft pockets several years later or left the hangar unfinished. These hangars were of Butler type with examples at New Castle, Delaware, and Scott Air Force Base in Illinois). The addition at New Castle was a Strobel & Salzman unit, making the final alert hangar half one type and half another. ADC also expanded several Butler hangars by adding two Strobel & Salzman pockets to the original hangar on each side—typically an event of the middle 1950s (with examples at Truax Air Force Base in Madison, Wisconsin, and Griffiss in Rome, New York).

ADC often clustered the ancillary structures that supported a FIS alert hangar near it at one end of the flightline. Ready crew dormitories were a design of Charles M. Goodman in 1951, with updated variants appearing by the middle 1950s and executed by regional architectural firms. Readiness and maintenance hangars were typically paired, sometimes sited near the alert hangar, and at other times completely separate along the main runway. When the latter occurred, hangars were often recycled from existing World War II infrastructure. Three generations of readiness and maintenance hangars were in use by ADC for FIS alert support. The earliest, again from 1951, was the design of Mills & Petticord in partnership with Luria Engineering. By mid-1953, Strobel & Salzman had redesigned the readiness-maintenance hangar. As of 1955, the readiness-maintenance hangar had become a much more modern structure of pull-through type, designed and engineered by Kuljian Corporation of Philadelphia (engineers of the SAC double-cantilever hangar of 1951). As of January 1957, Strobel & Salzman designed a second-generation FIS alert hangar that increased the size (especially length) of the individual aircraft pockets to accommodate the longer F-101B. ADC and TAC erected very

few second-generation hangars, with the commands instead modifying their existing hangars through new doors on all Butler hangars, and through front and rear lower door extensions on all Strobel & Salzman hangars. In all instances, the longer aircraft pockets indicated assignment of the F-101B, F-102, or F-106. Also during the period of 1956-1957, ADC added aircraft shelters (Strobel & Salzman) at many of its cold, windy northern tier bases. From 1958-1959 into 1962, the command provided electronics and weapons calibration structures adjacent to the FIS alert hangar for the F-101B and its linkage to SAGE. These were Butler buildings adapted by Kuljian Corporation to suit their specialized purpose. Squadron operations buildings and flight simulators completed FIS areas, with considerable design variation for the former at the regional level.

Weapons storage for ADC FIS alert also was multi-generational. At the outset of the 1950s, structures were simple. The command typically constructed them in the vicinity of the readiness-maintenance hangar(s) and stored small munitions (for machine-gun armed fighter aircraft). With receipt of the F-86D for the interception mission, ADC upgraded munitions to folding-fin air-to-air rockets (FFARs) and guided air rockets (GARs). The New York engineering firm Weiskopf & Pickworth designed a two-unit weapons storage facility (Unit A and Unit B) in 1954 and 1955 to house these munitions. The third-generation munitions igloo for ADC FIS was for the nuclear-tipped MB-1 Genie, a guided missile carried by the F-89J, F-101B, and F-106. Weapons storage areas for the Genie were segregated, usually not adjacent to the FIS alert cluster and often in a secure compound on the opposite side of the runway. For the second-generation weapons facility, a checkout and assembly structure accompanied storage. Black & Veatch of Kansas City designed and engineered the Genie stall-type storage igloos in mid-1956, with construction through 1958. The firm had experience with atomic weapons storage from its work at Los Alamos as of 1946 and was responsible for the atomic and thermonuclear weapons storage areas built at selected SAC bases during the late 1940s into the early 1950s. ADC programmed for 23 storage sites for the Genie, also known as the Ding-Dong and Hi Card, at a cost of $27 million. At some ADC and TAC installations, the sequence of weapons storage structures tells the story of which aircraft the commands stationed on alert, for specific years and deployed weapons—simultaneously indicative of a location's period of high importance, and often, when that period ended.

Alert Configurations at Air Force Materiel Command Installations

Among the installations under ARDC / AFSC and Air Materiel Command / AFLC, bases hosting FIS alert were Kirtland, Griffiss, Wright-Patterson, Hanscom, Edwards, and Eglin. Formal plans for FIS alert infrastructure at the first four of these installations date to 1951, with construction into 1952-1953. When President Truman federalized the first 15 FIS squadrons in February 1951, locations included Albuquerque, Dayton-Columbus, and central and western New York.[95] By July, CONAC—handling the air defense mission—assigned FIS on a permanent change-of-station basis to Kirtland and Griffiss (without infrastructure).[96] Soon, Kirtland, Griffiss, and Wright-Patterson each supported an economy Butler hangar. A Butler hangar was usually evocative of an early priority air defense mission, but at Wright-Patterson also exemplified Air Materiel Command's role in developing prefabricated infrastructure for the Air Force.[97] ADC additionally collocated ADCCs at Kirtland, Griffiss (at Hancock Field), and Wright-Patterson. Typically, the presence of FIS alert infrastructure at ARDC / AFSC and Air Materiel Command / AFLC bases[98] is indicative of a standard ADC or TAC tenant mission, but in two instances had an unusual connection to R&D within Air Materiel Command (at Wright-Patterson) and ARDC (at Hanscom through linkage with the Experimental SAGE Direction Center on base). The depot installations under Air Materiel Command (later under AFLC) supported only a single FIS alert tenant mission, at Griffiss. Depots were more likely to host a SAC alert tenant mission (see discussion below), but were generally not hosts to alerts of any kind in high numbers. The Eglin facility was actually a conversion of a preexisting SAC alert compound for use by TAC fighters in the early 1970s. The presence of ANG alerts at ARDC / AFSC and Air

Materiel Command / AFLC installations is unresearched, but likely existed in temporary configurations for short periods (without permanent infrastructure). One known example is Brooks Air Force Base, which sustained an ANG FIS alert in 1956.[99]

The first top-priority ADC FIS at ARDC / AFSC and Air Materiel Command / AFLC installations was located at Kirtland in New Mexico. The Albuquerque - Los Alamos region was responsible for critical work towards improved atomic, and then thermonuclear, bombs. As of February 1950, Albuquerque was the only area in the continental United States that sustained a fighter wing for air defense. ADC assigned the 81st Fighter-Interceptor Wing, activated in January 1949, to manage a circular defense area (see Plate 74). A four-pocket Butler FIS alert hangar was under construction at Kirtland as of June 1951, with a readiness crew dormitory and F-86 flight simulator adjacent to the hangar as of 1952-1953. Two World War II hangars functioned as readiness and maintenance facilities. ADC located them separately from the core FIS cluster. The ADCC sat in close proximity to the alert hangar and its two ancillary structures. Kirtland's FIS mission is particularly illustrative of the intense fluidity of the air defense mission of the 1950s. At mid-decade, the Air Force lengthened the runway at Kirtland with work underway in 1954. The FIS alert hangar at Kirtland evaded obsolescence only due its inherent structure. The Air Force unbolted the hangar from its concrete pad and moved it down to the new end of the runway to the east. ADC created a new FIS alert area, with ramp and apron, by completing the compound with a standard Strobel & Salzman maintenance hangar of 1953 (built at Kirtland in 1954-1955) and a second readiness crew dormitory (in 1957).[100] ADC also replaced the front and rear doors of the relocated alert hangar to accommodate the longer fighter jets of the decade ahead (see Volume II, Chapter 8).

Planning for a FIS alert area was also very early at Wright-Patterson. ADC initiated site work for a permanent alert compound to house the 97th FIS in mid-1951.[101] The 97th Fighter Squadron had been in place on base since 1949, with its alert crew quarters in the western section of the Air Transport Squadron hangar designed by Albert Kahn in 1940. By March 1951, the 97th Fighter Squadron additionally occupied seven temporary structures nearby.[102] The command first considered erecting the standard Strobel & Salzman hangar (also having considered the hangar at Kirtland),[103] but by autumn had revised its FIS alert site planning for the economy Butler hangar.[104] Strobel & Salzman's final design for its FIS alert hangar dated to April 1951, while Butler had been commissioned to develop an economy version as of mid-March. Possibly other Air Force needs—particularly those tied to the Korean War and to SAC's priority missions of this same time—affected the choice of the earliest alert hangars (shifting them towards Butler hangars). It is also possible that materials shortages or production problems tied to the Strobel & Salzman hangar necessitated a backup plan. Air Materiel Command was concurrently working with Butler on an aluminum version of its FIS alert hangar. The aluminum alert hangar was in test along with its steel version (as single bays) at the Butler plant in Galesburg, Illinois, during April-May 1951 as a Wright-Patterson contract. The lighter aluminum hangar was intended for shipment to the Arctic. Butler erected a full-scale aluminum alert hangar at Galesburg, with representatives of both Air Materiel Command and ADC visiting the test site. Butler commented on the project.

> It was required that this building be completely transportable by air before assembly, and for this reason aluminum was used in a majority of the design...[The] large door had to be designed so that it could be opened in 45 seconds by one man. Since the building is to be located in Arctic regions, it was necessary to insulate it completely.[105]

The Air Force decided against the aluminum hangar, working toward other solutions for FIS alert in extremely cold regions. The Butler alert hangar, as built at Wright-Patterson in 1952, was a typical steel structure (Plate 94).

Ancillary structures accompanied the alert hangar at Wright-Patterson. Air Materiel Command, in conjunction with ADC, did not give up entirely on aluminum construction for FIS buildings. At Wright-Patterson, the readiness-maintenance hangar for the FIS alert area was aluminum. The Reliable Engineering Corporation of Altoona, Pennsylvania, designed the hangar, using an IDECO building. IDECO, the International Derrick and Equipment Company, was a division of the Dreisser Equipment Company of Columbus, Ohio (with other branches in Beaumont, Texas, and Torrance, California). The Reliable Engineering Corporation designed the hangar in February 1952 (Plate 95). Construction was underway as of August and was completed only three months later. The hangar appears to have been one of a kind across ADC alert areas. In 1953, ADC added a small flight simulator inside the hangar. During this same period, the command completed the support cluster for the FIS alert with a readiness crew dormitory immediately adjacent to the readiness-maintenance hangar (in late 1952) (see Plate 95), also adding the Unit A weapons storage structure for FFARs and GARs (in mid-1954). As of August 1955, the 97th FIS transitioned to the 56th FIS for ADC alert, with plans to expand the Butler hangar from a single-squadron structure to an eight-pocket hangar in January 1956.[106] Although this secondary expansion did not take place, it is indicative of a more pronounced ADC presence at Wright-Patterson at mid-decade. (The command had just finished an ADCC on base.) ADC also planned to add four aircraft shelters and multicubicle magazines for the nuclear-tipped MB-1 Genie (unbuilt). ADC discussed bringing the MB-1 to the base as of August 1956—that is, from the earliest days of planning for the weapon.[107] As of 1958, the ADC Special Weapons System Project Office for the Genie was functional at Wright-Patterson, with earlier meetings for the Genie held at the Air Force Special Weapons Center at Kirtland. The 56th FIS deactivated at the installation in March 1960.[108]

The ADC FIS hangars at Griffiss (a Butler hangar) and at Hanscom (a Strobel & Salzman hangar) also supported air defense alert, but each initially had test missions. At Griffiss, ADC erected a Butler four-pocket hangar in 1951 for the 27th FIS (activated at the installation in August 1950). Griffiss was a special case in many ways. The base functioned as home to the Rome AMA and the RADC. ADC had sited one of the original 11 ADCCs nearby at Hancock Field in Syracuse and added SAGE Combat and Direction Centers there by the late 1950s (alternately known as Syracuse Air Force Station). As an important SAC installation (with that command the base host after 1970), Griffiss had a much higher profile for alert missions than many bases. The command expanded the FIS alert hangar to eight pockets in 1954, making modifications to its front and rear doors in 1956 for the F-101B (Plate 96). In July 1959, the 49th FIS (from Hanscom) replaced the 27th at the installation, operating at Griffiss until the end of the Cold War. The air defense alert area contained a readiness crew dormitory and a squadron operations building, a Unit A rocket storage checkout and assembly building, MB-1 Genie storage magazines (segregated away from the alert area), and a weapons calibration shelter for the F-101B. The command reused World War II hangars for readiness and maintenance.[109] In 1952, at the outset of the FIS alert mission, Griffiss also provided its 6531st Flight Test Squadron for off-site stationing at Hanscom. The 6531st supported radar and communications R&D underway by MIT. The squadron deployed to Massachusetts for its mission and returned to Griffiss for maintenance. As the Lincoln Laboratory geared up for SAGE, Headquarters ARDC in Baltimore decided to station a Flight Test Squadron at Hanscom full-time as a component of the 6520th Test Support Wing. The newly formed squadron drew upon resources at Griffiss, replacing the loaned 6531st Flight Test Squadron. Griffiss provided 16 aircraft for the mission to Hanscom, with the RADC also heavily involved.[110]

As of May 1954, construction was underway at Hanscom for an alert complex to support a more permanent FIS. By that date, Griffiss no longer provided assistance to the base. The FIS cluster at Hanscom included a standard Strobel & Salzman four-pocket hangar, a readiness crew dormitory, a Strobel & Salzman readiness-maintenance hangar, and a Unit A rocket storage, checkout and assembly building (Plate 97).[111] The 49th FIS activated at Hanscom in November 1955. The 49th FIS

Plate 94: Butler Manufacturing Company. 4-Pocket FIS Alert Hangar (Building 30152), Wright-Patterson Air Force Base, 1951. Photograph of 10 February 1953. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

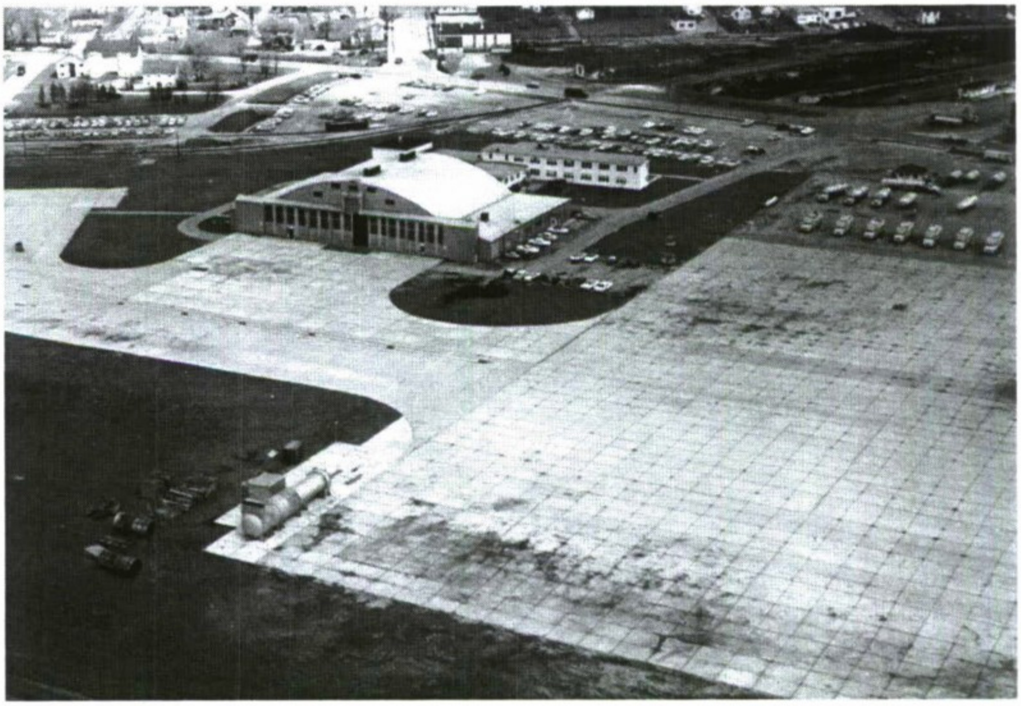

Plate 95: The Reliable Engineering Corporation and IDECO. ADC Readiness Hangar (Building 30153), Wright-Patterson Air Force Base, 1952. Readiness crew dormitory and Unit A weapons storage to the rear of the hangar. Photograph of 21 April 1961. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

Plate 96: Butler Manufacturing Company. 8-Pocket FIS Alert Hangar, Griffiss Air Force Base, 1951 and 1954. (Flightline façade.) Photograph of July 2000. K.J. Weitze for EDAW, Inc.

was on ADC alert, but also assisted in the testing of electronics links to the Experimental SAGE Direction Center abutting the Lincoln Laboratory. Its dual mission was much like that of the SAGE Direction Center at Gunter Air Force Base in Montgomery, where the command post split its time between test and training tied to the Bomarc test squadrons at Eglin and slowly came on line as a fully operational SAGE center. The 49th FIS supported Project Lincoln most intensely during the 1955-1957 period. One example of a crossover mission was the testing of the F-86L during 1956-1957. ADC authorized 25 F-86Ls for the 49th FIS. The squadron became among the very first to begin receiving the aircraft in July 1956. The F-86L was an upgrade of the F-86D, featuring improved electronic interception aids. ADC used the F-86L at Hanscom, as did MIT, to test data-link programs explicitly for SAGE. The command coordinated 49th FIS testing of the F-86L with the Lincoln Laboratory.[112]

In the first six months of 1957, the 49th FIS flew 172 SAGE data link missions. Other SAGE tasks also occupied the 49th.

> [T]he 49th FIS has become more and more integrated into the SAGE testing of Lincoln Laboratories [*sic*] at L.G. Hanscom Field. This phase of operations will continue to be a prominent portion of operational requirements.
>
> In addition to flight testing for the SAGE system, the unit has been designated a testing facility for communications system testing, and

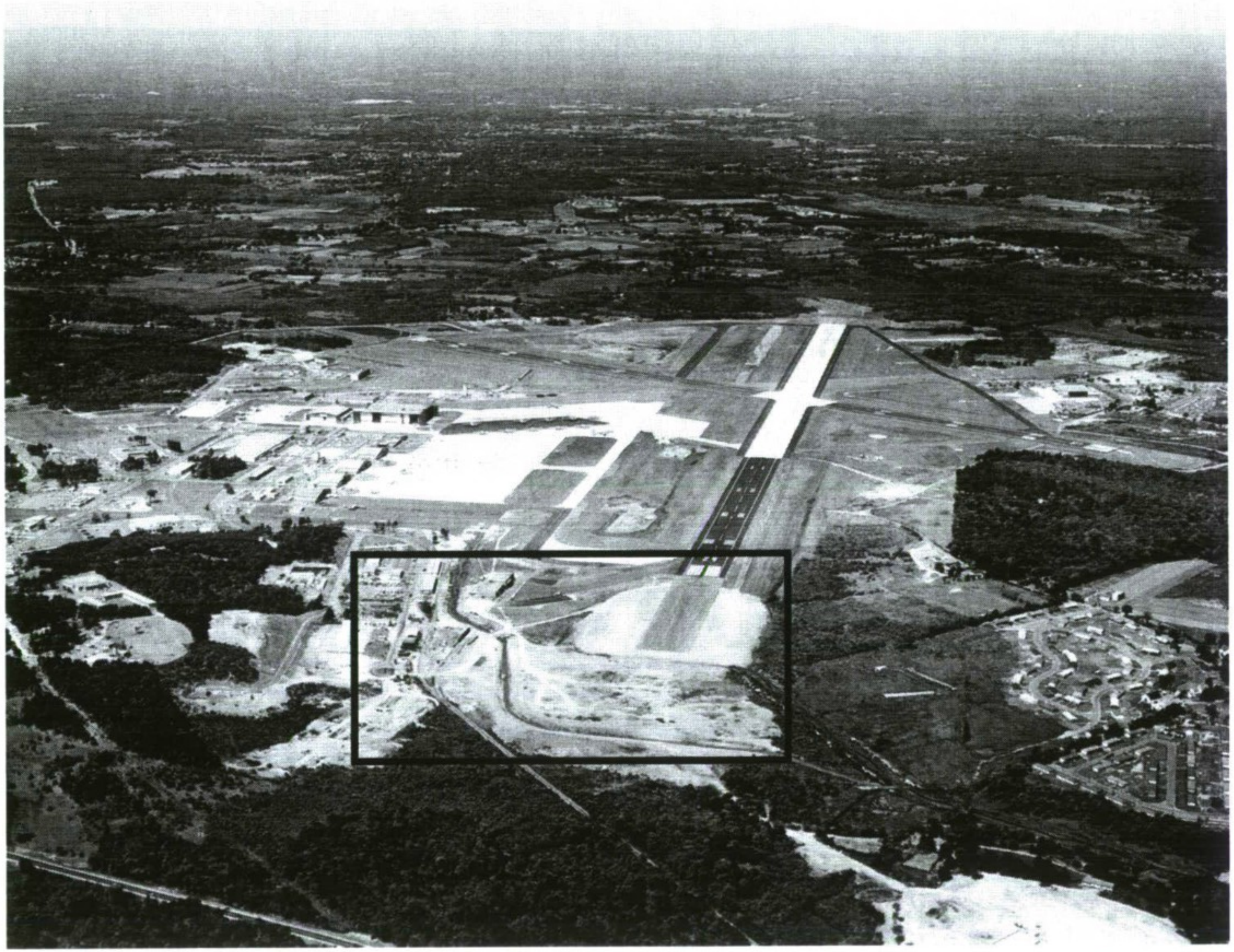

Plate 97: Strobel & Salzman. 4-Pocket FIS Alert Hangar (Building 1840), with alert apron and taxiway, Hanscom Air Force Base. Photographed by Laurence Lowry 8 July 1960. Courtesy of the History Office, Electronic Systems Center, Hanscom Air Force Base.

> has had this equipment installed during this period. ...the communications system was integrated side by side with present Air Defense Command Operational systems.[113]

SAGE tests continued to be "the primary mission of the squadron" into 1959, with "bi-weekly Sage support missions." SAGE projects included Fast Talk (to test data link reliability) and Pegasus (concentrated on the system's versatility in managing FIS intercepts). The 32nd Air Division, then managing the Boston SAGE Sector, also ran exercises in which the 49th FIS participated.[114] In July 1959, the 49th FIS transferred from Hanscom to Griffiss, which concluded the fighter-interceptor mission on base.

ADC planned a FIS alert for Edwards as of 1961. The command first discussed moving the 15th FIS from Davis-Monthan Air Force Base in Arizona to one of four Southern California locations: Oxnard, Edwards, George, or March Air Force Bases. For this late FIS alert posture at Edwards, however, ADC did not act on its plans for the 15th FIS. Instead the command established alert at the base for the 329th FIS as of March 1963. The 329th FIS flew F-106s, an all-weather interceptor that was a follow-on to the F-102B. Infrastructure supporting deployment of the F-106 at Edwards included a Kuljian weapons calibration shelter, adaptation of an existing ready crew flightline dormitory of 1950, reuse of a World War II hangar for ready maintenance, armament and electronics shops, and a flight simulator. ADC did not erect an alert hangar, a very unusual configuration for air defense alert.[115] The 329th FIS was actually a detachment from the nearby George Air Force Base. George had a full complement of alert structures from 1954 forward (including a Butler alert hangar and a sizable cluster of multicubicle magazines for storage of the MB-1 Genie). Detachment 1 of the 329th FIS was on alert at Edwards from early 1963 through July 1967, with four F-106s positioned in the open along a taxiway for scrambling within the Los Angeles Air Defense Sector (see Volume II, Chapter 3).

The FIS alert at Eglin was also unusual for the overall air defense effort within the continental United States. Fighter alert arrived at the base even later than at Edwards and was under the jurisdiction of TAC.[116] The command established a fighter squadron at Eglin in June 1965, partially in response to the weakness of air defense for the Southeast during the Cuban missile crisis. Air defense, including alert, had been lax in the region as early as 1956. In that year, the seven states of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana had supported a FIS force of only two squadrons at a time when there were 29 Air Force bases in the area. FIS in the Southeast had represented only three percent of the total air defense squadrons on alert, but had covered 15 percent of the states in the country. By late 1957, ADC had planned for an alert FIS at Pinecastle (after 1958, McCoy) Air Force Base near Orlando to replace regional emergency squadrons created earlier in the decade. In December 1958, two defectors from Castro's forces had flown a Cuban B-26 without challenge to Florida, landing at the Daytona Beach airport.[117] Even with the notoriety caused by the event, the air defense situation was only marginally different by 1960. Florida's FIS were often temporary in assignment and included fighters at Naval Air Stations as stopgap measures. Only in 1959 did ADC add its fourth permanent FIS for the region, at England Air Force Base near Alexandria, Louisiana, 170 miles northwest of New Orleans.

With the implementation of a plan to augment air defenses in southern Florida as of January 1961—the Southern Tip program—the Air Force acknowledged that its defenses were indeed sparse and that Cuba, with its known receipt of Soviet 27 MiG-15s and seven MiG-19s, could successfully conduct "nuisance raids against populated areas." As a part of Southern Tip, ADC assigned fighter-interceptor aircraft from the 4756th Air Defense Wing at Tyndall to Homestead near Miami and moved Navy interceptors to Key West Naval Air Station. TAC interceptors went on alert at both Tyndall and Homestead, with the additional backup of F-101Bs armed with the MB-1 Genie planned

from the existing FIS at Charleston Air Force Base. Navy interceptors were also on alert at Key West and the Naval Air Station at Richmond, Florida.[118] By July 1961, the extemporaneous FIS alerts included one at the Miami International Airport to replace the Tyndall detachment previously at Homestead while that airfield underwent runway improvements.[119] The FIS alerts continued to be mobile for southern Florida, with Homestead again in use by the 331st FIS during the Cuban missile crisis of late October 1962 (deployed from Webb Air Force Base in Texas). At Homestead, ADC set an interesting precedent for FIS alert in the 1960s: the command used the SAC alert area there for air defense needs.[120] SAC's state-of-the-art alert facility for its bombers had been in place at Homestead only since mid-1959. ADC's adaptation of the SAC alert area at Homestead directly foreshadowed the treatment of similar physical infrastructure at Eglin.

Air defense was not a priority mission in Florida even after the Cuban missile crisis of October 1962, leaving the South Atlantic Coast and the Gulf of Mexico vulnerable. Once the United States geared up for the Vietnam War, air defense plummeted for the Air Force nationwide. In Florida, ADC sustained FIS alert at Key West (Navy) and Tyndall, Homestead, and Patrick during the middle 1960s. A FIS squadron at Patrick became a dispersal detachment for Homestead, again using the SAC alert area. Occasional incidents continued to demonstrate the weakness of air defense in the Southeast. In October 1969, another defector from the Cuban Air Force flew an armed MiG-17 completely undetected from Havana to Homestead. Two years later, a plane of Cuban officials flew into range of New Orleans, unobserved until the pilot requested permission to land. By 1971, TAC had occupied the SAC alert area at Eglin for six years. TAC took over the infrastructure at the conclusion of the SAC alert mission at the installation (see discussion below). After the New Orleans incident, a Congressional investigation reported that "deterioration of the warning systems and active defenses had made the 1,500-mile southern border between Florida and California practically defenseless." In May 1972, Secretary of Defense Melvin R. Laird demanded that interceptors go on alert at four bases in "previously unprotected areas." Reestablished was an alert FIS at Charleston, and three in Florida. The Florida FIS uniformly adapted SAC alert areas for high profile alert FIS. Fighter aircraft in a SAC alert area dated to 1962 at Homestead; to 1965 at Eglin; and, to 1969 at McCoy. At McCoy, TAC reused not only the SAC alert apron, but also the available B-58 shelters (as improvised alert hangars). TAC added a five-pocket standard hangar of its own to the rear of the former SAC area at Eglin in early 1971. By mid-1975, TAC was still on alert at Eglin in its former SAC area. By this date, TAC had placed two Butler shelters on the terminating parking stub of the SAC herringbone alert apron (Christmas tree). The command created an *ad hoc* two-pocket alert hangar similar to the adapted B-58 shelters at McCoy. Two alert crew trailers were parked adjacent, with the assumption that the SAC alert crew quarters (its molehole) served as the crew dormitory. The Butler buildings had been SAC's, originally in use as engine buildup facilities.

Strategic Air Command

The Bomber Alert Network

While ADC initiated alert for its interceptors in 1951, SAC waited until 1954 to begin planning toward alert for its bombers. In that year, the command discussed a general scheme that included alert hangars, organizational maintenance hangars, and aircraft shelters. In 1955, SAC had a study in progress for a "structure that will satisfy all three (3) requirements" [alert hangar, maintenance hangar, and shelters].[121] The specifications of this structure are unknown, and apparently nothing came of it. By mid-decade, the command had grown to prestigious prominence in the Air Force with 38 SAC installations in the continental United States and 13 overseas. SAC's dominance of Air Force planning made the command bold enough to request that its bases be increased to 329 by July 1959, truly a magnitude beyond planning by either ADC or TAC. The command undertook active alert as of late 1956. At this stage, SAC used existing buildings at the end of the primary runway for

the mission. SAC conducted surveys as to how to best implement interim alert and renovated needed structures in 1957. The command set aside a portion of the main aircraft parking ramp for SAC bombers, with security for the munitions-loaded aircraft. SAC fenced the perimeters of its interim alert crew quarters and the bomber parking area, manning access gates. Of particular note, the command began to assess how long each component of alert should take: what position should the parked alert aircraft maintain? where? how could alert crews best reach their planes in a timely manner? what were the best routes between key infrastructure? what timeframe constituted a successful alert? Before 1956, a six-hour timeframe existed between the notice to take off and airborne planes. During alert, SAC's first timeframe was one hour. By 1961, with operational alert infrastructure in place, the alert timeframe was 15 minutes. SAC anticipated that a quarter-hour was the window from "detection to detonation" for Soviet ICBMs inbound for the United States.

Once SAC firmed up its interim alert policy by 1957, the command started serious planning for the program's required infrastructure. Several parking configurations were active for SAC alert at that time, and variations on parking stub patterns for the command's bombers were evolving toward one that would be adapted for alert. The first step accommodating improved takeoff times was the placement of mass aircraft parking and stubbed arrangements at the very end of the runway. The use of effective stub patterns was the second step, with a herringbone pattern tried for B-47s at McConnell Air Force Base in Kansas. In some cases, SAC placed nose docks for its bombers at the parking stubs. These were likely the "operational shelters" referenced in its discussions of 1954-1955. Nose docks and a double-cantilever maintenance hangar both dated to 1951, and thus were available SAC infrastructure under consideration for alert by mid-decade. SAC chose a tentative alert apron by the end of 1956, well aware of the alert solution in use by ADC. The command initially decided upon a 90-degree parking stub for individual aircraft on alert, but then changed to the 45-degree herringbone pattern. The alert ramp at the end of the runway was also at a 45-degree angle, mirroring that of ADC. Sometimes ADC and SAC alert areas were at the same end of a runway, on opposite sides. At other times, ADC occupied an alert area at one end of the runway, and SAC at the other. The command moved quickest to get its bombers positioned for priority alert, beginning construction on its alert aprons before undertaking that for alert crew quarters. At installations where the 90-degree alert apron was already in progress, SAC either called for a redesign to the herringbone configuration (soon nicknamed a Christmas tree) or left it in place for tankers on alert. (The 90-degree aprons are always indicative of SAC's earliest construction for alert.) The Christmas tree illustrated the command's highest alert needs, those for B-47 and B-52 bombers. As of October 1957, just one of the new Christmas trees was completed: at Wurtsmith Air Force Base in Michigan.

In 1961, when SAC finished buildout of its alert program, most aprons were Christmas trees. A small number of aprons featured the 90-degree stub pattern and a very few were anomalies. The 65 SAC alert compounds also all featured permanent alert crew quarters. SAC placed its planes on the existing rectangular apron near the end of the runway or expanded a taxiway into a segregated alert pen at installations where the terrain did not allow construction of a Christmas tree or when purchase of additional land was not possible. The 90-degree alert configuration was generally five- or nine-stub in design. Christmas trees were much more varied, with three typical schemes and at least four sizes. One version featured a single large apron with four to 11 individual stubs. SAC used the end stub sporadically. In other cases, the command achieved an increased capacity through the design of two aprons angled toward a shared taxiway. At times these aprons were of equal size, while on other occasions they were radically different in size and configuration (varying from combined small and large Christmas trees, to one large Christmas tree and a half-tree). As of late 1957, none of the front-runner alert aprons included permanent crew quarters. SAC turned to formal alert in October 1957, following the Soviet launching of Sputnik. The command placed 11 percent of its 1,528 bombers and 766 tankers on alert. SAC continued to adapt barracks and dormitories near the apron, also bringing house trailers to selected sites in early 1958. The Second Air Force at Barksdale in Louisiana was the first to test the idea of trailers for alert crew quarters, with seven other SAC bases receiving Travelite

trailers late in the year. In April 1958, Leo A. Daly of Omaha completed drawings for a permanent readiness crew facility. The alert crew quarters accommodated three sizes of alert: 70 men (18,000 square feet), 100 men (22,500 square feet), and 150 men (31,000 square feet). Soon known as moleholes, the quarters featured one story below ground or heavily bermed, and one above. Leo A. Daly had substantial experience for the Army during World War II and had also designed SAC's first underground command post at Offutt in 1955. Built of reinforced concrete and concrete block, moleholes were uniformly windowless, with tunnel exits for the floor underground. In most locations, corrugated steel covered the tunnels, although rampways were an alternate approach (most often found in mild climates). In 1959, SAC also purchased a fleet of station wagons (539) and panel trucks (93) to transport airmen to and from alert duty.

As of April 1959, SAC had 64 moleholes in progress or slated for construction. Two additional moleholes were in design (Ramey and R.I. Bong), with a 67th cancelled for Headquarters SAC at Offutt. The SAC moleholes represented the Second, Eighth, and Fifteenth Air Forces, and their tenant bases. The Air Force ultimately cancelled construction for R.I. Bong Air Force Base in Wisconsin, which was to be a combined SAC and TAC installation. The final 65 moleholes included 10 of the 150-man facilities, 10 of the 100-man, and 45 of the 70-man. The command built seven of the moleholes outside the continental United States with six at the Canadian sites of Goose Bay (Labrador), Ernst Harmon (Newfoundland), Cold Lake, Churchill, Namao, and Frobisher (four of these as Royal Canadian Air Force tanker refueling bases), and one in Puerto Rico (Ramey Air Force Base). At installations where SAC was a tenant, its alert compound included a much bigger cluster of ancillary structures in support of the molehole and Christmas tree. At the top priority alert bases the Hound Dog / Quail, a nuclear weapons system of the early 1960s, augmented alerts. SAC emplaced this air-launched guided missile at 29 of its alert areas (the Hound Dog), with 14 of the 29 also receiving its paired decoy missile (the Quail). The SAC alert infrastructure of the molehole and Christmas tree was most important during the transition from a Soviet bomber threat to one of ICBMs in 1959 and into the early 1960s. After SAC built missile launch silos for the Atlas and Titan, the full web of SAC bomber and tanker alerts was less critical. In addition, SAC strategic planning changed significantly in the late 1950s, with bases in the central continental United States becoming much less important for alert than those across the northern tier. And finally, the shift from the B-47 to the B-52 affected which alert locations sustained the longer missions. Many of the 65 SAC moleholes and Christmas trees had short lives very similar to ADC generational command posts and FIS. SAC alert underwent an abrupt decline after about 1963-1964.

SAC expanded its alert compounds two times during later periods of the Cold War. The first occurred as part of its satellite alert basing plan of 1967-1975 (see below), while the second reflected escalation during the Reagan years of the middle 1980s. Both later SAC alert configurations also involved new nuclear weapons systems: the short range attack missile (SRAM) in the early 1970s and the air-launched cruise missile (ALCM) during 1985-1987. SAC required special cubicle magazines with associated checkout and assembly structures for these sequential weapons systems, as it had for the Hound Dog. The Kansas City engineering firm of Black & Veatch designed the structures for all three systems, continuing efforts begun for special weapons storage in the late 1940s in New Mexico. For the final SAC alert of the middle 1980s, SAC also often expanded the original molehole of 1958-1960. The command typically doubled the structure in size through an addition and renovated exterior tunnels. The modified moleholes of the late Cold War only marginally resembled those of the war's early years.

Alert Configurations at Air Force Materiel Command Installations

SAC alert presence on ARDC / AFSC and Air Materiel Command / AFLC installations was entirely a strategic choice. Two early Air Materiel Command bases received a SAC alert compound: Clinton County in Ohio (1946-1949) and Fairchild in Spokane, Washington (1945-1947, 1952-ca.1955). In

both cases, however, the installations had become SAC bases as of the late 1940s. Four other ARDC / AFSC and Air Materiel Command / AFLC installations supported SAC alert during the late 1950s into the early 1960s, with a continuing SAC presence for varying lengths of time thereafter. The group included two depot bases (Griffiss in New York and Robins in Georgia), and two R&D bases (Eglin in Florida and Wright-Patterson in Ohio). The Air Force assigned Griffiss to Air Materiel Command / AFLC and ARDC before 1970, when SAC became the base host. SAC was a tenant on Griffiss at the outset of its alert posture at the installation. A SAC strategic wing was on alert there from 1958 to 1963, with a SAC bomber squadron continuing alerts at the molehole from 1963 to the end of the Cold War. At the other three installations (Eglin, Robins, and Wright-Patterson), SAC was also a tenant. SAC sustained an alert mission at Eglin from 1958 into 1963, with the follow-on SAC bomb wing there until early 1965. The lengths of the SAC tenant mission varied at Robins and Wright-Patterson, with strategic wings there from 1959 into 1963. Bomber squadrons followed from 1963 to 1975 (Wright-Patterson) and from 1963 past 1986 (Robins).[122] As tenants, all four SAC alert missions, supported 70-man moleholes, Christmas tree alert aprons, and large ancillary compounds. SAC also assigned each the Hound Dog / Quail, indicating that although their moleholes and alert aprons were modest, these alerts were among those of the highest priority for command at the outset of its program.

The earliest SAC alert mission among the group was at Eglin, although construction was underway at Griffiss, Robins, and Wright-Patterson as of January 1959.[123] (Griffiss was in a top-priority group of 10 SAC alert compounds in progress by mid-1958—each at a northern-tier installation.) The SAC alert facility at Eglin was one of four in Florida: at Eglin, Homestead, McCoy, and MacDill Air Force Bases. Of some note, while ADC was not able to effectively strengthen its air defense command posts or FIS alert in Florida prior to the Cuban missile crisis in 1962, SAC had thoroughly anticipated Castro's rise to power in January 1959. The command had begun working toward a strategically powerful presence in Florida as soon as Castro's guerrillas began to destabilize Batista's government in 1956-1957. The Florida SAC alert wings featured three 100-man moleholes for southern Florida (McCoy, MacDill, and Homestead). This group represented nearly one-third of the 100-man moleholes nationwide. SAC assigned the nuclear-tipped Hound Dog to each of the four Florida bases on alert. The decoy Quail is unresearched for McCoy, MacDill, and Homestead, but was in place at Eglin.[124] In Florida, preparations to attack were vividly represented through SAC alert, while those for defense—through ADC command posts and FIS alert—were not.

SAC alert at Eglin, Robins, and Wright-Patterson sustained a large cluster of ancillary buildings. The command built up these discrete areas almost as miniature SAC bases at their host installations. Combinations of structures supporting the molehole and alert apron included: an operations building, industrial building, intelligence training facility, maintenance-readiness nose docks, fuel system docks, rectangular refueling apron, Hound Dog / Quail service shop, separate Hound Dog and Quail missile run-up shops, munitions storage, and varied generic buildings. SAC designated the 4135th Strategic Wing at Eglin on 1 December 1958, with the basic utilities infrastructure for its alert site nearly finished by the end of the month. Alert and operational aprons were 40 percent complete, and an armament and electronics shop, combined squadron operations and target intelligence building, general purpose aircraft shop, and munitions storage were underway. Air Materiel Command had the responsibility to procure the required nose docks for the alert area (true for all bases and commands). Nose docks were "shippable," prefabricated infrastructure. The Air Force did dismantle and move bomber nose docks from one installation in a region to another, although these were very large structures. For Eglin's SAC area, Air Materiel Command planned to dismantle 12 multipurpose nose docks at Donaldson Air Force Base in South Carolina for dispersement where needed. The docks serviced the B-52. SAC requested five docks for Eglin, but received three. The base extended its runway from 10,000 to 12,000 feet as of late 1957 in preparation for the SAC mission.

While SAC was constructing its alert facilities in the United States and northeastern Canada, budgets for facilities were at a premium. These constraints led to integrating trainers in the squadron operations building, as well as placing a B-52 simulator inside the post-flight nose dock. The nose docks at Eglin had typical missions of periodic aircraft inspection, post-flight checks, and unscheduled maintenance. As of March 1959, the Hound Dog and Quail support buildings were in construction. As built, the key facilities at the SAC alert area were the four / five-stub Christmas tree, refueling apron, 70-man molehole, Hound Dog and Quail infrastructure, three nose docks, fuel systems dock (added in 1961), armament and electronics shop, general purpose repair shop, squadrons operation and intelligence-training building, fire station (added in 1960), and two jet fuel storage tanks (Plates 98-99). Eglin did not support a separate wing headquarters on site as had been originally planned, nor a barracks and mess facility. (SAC integrated these latter functions at Eglin's main cantonment.) Yet, SAC alert at the base was much more elaborate than was typical at other than a primary SAC base. Eglin was one of the earliest SAC alert areas under construction at a tenant installation and was thus among the first to require a larger cluster of ancillary buildings in support of its molehole and Christmas tree.

SAC's alert planning was not fully set at the beginnings of its buildout, like many programs within the Air Force during the late 1950s. Variation existed from base to base for the very first alert compounds in an effort to shift from an elaborate compound of buildings to one less so. (Although moleholes were completely standard everywhere.) The Air Force Directorate of Installations had started to address streamlining SAC's infrastructure as early as late 1956. At that date, the Directorate suggested that SAC squadron operations, target intelligence, fire station, warehouse, and shops be combined in a single structure. Planning toward this end took time, and by 1958 three prototype "composite" structures were authorized at the SAC bases of Amarillo and Sheppard in Texas, Beale in California, and Grand Forks in North Dakota. As finally designed, the economy

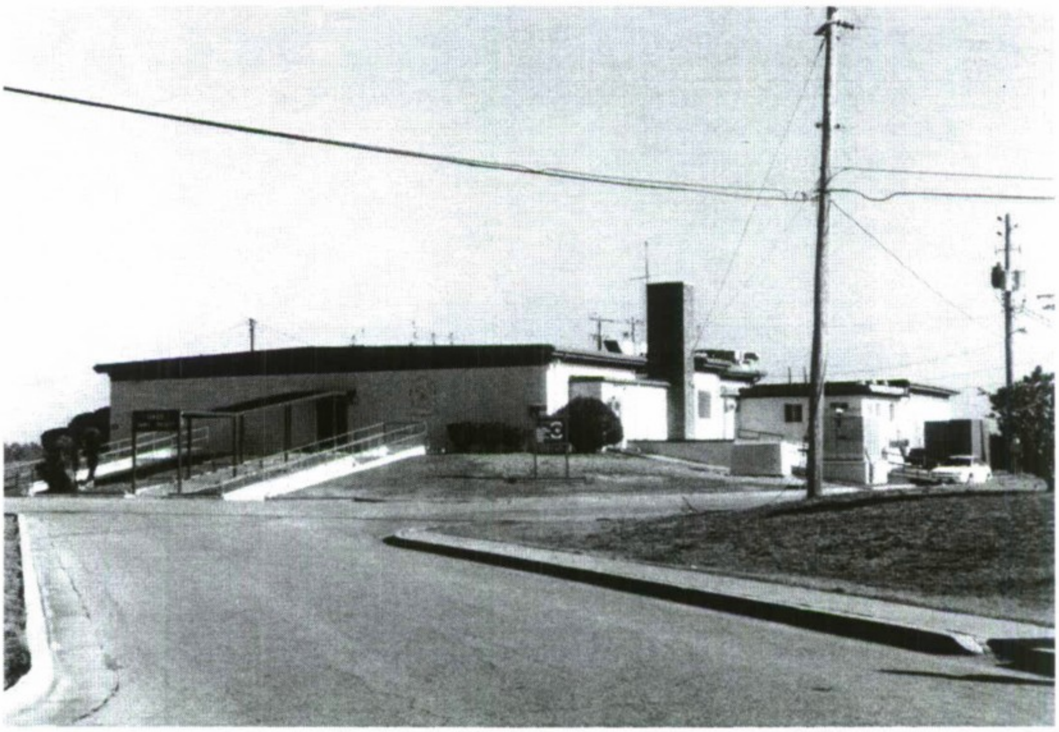

Plate 98: Leo A. Daly. 70-Man Molehole (Building 1355), Eglin Air Force Base, 1958. Photograph of February 2000. C. Dolan for EDAW, Inc.

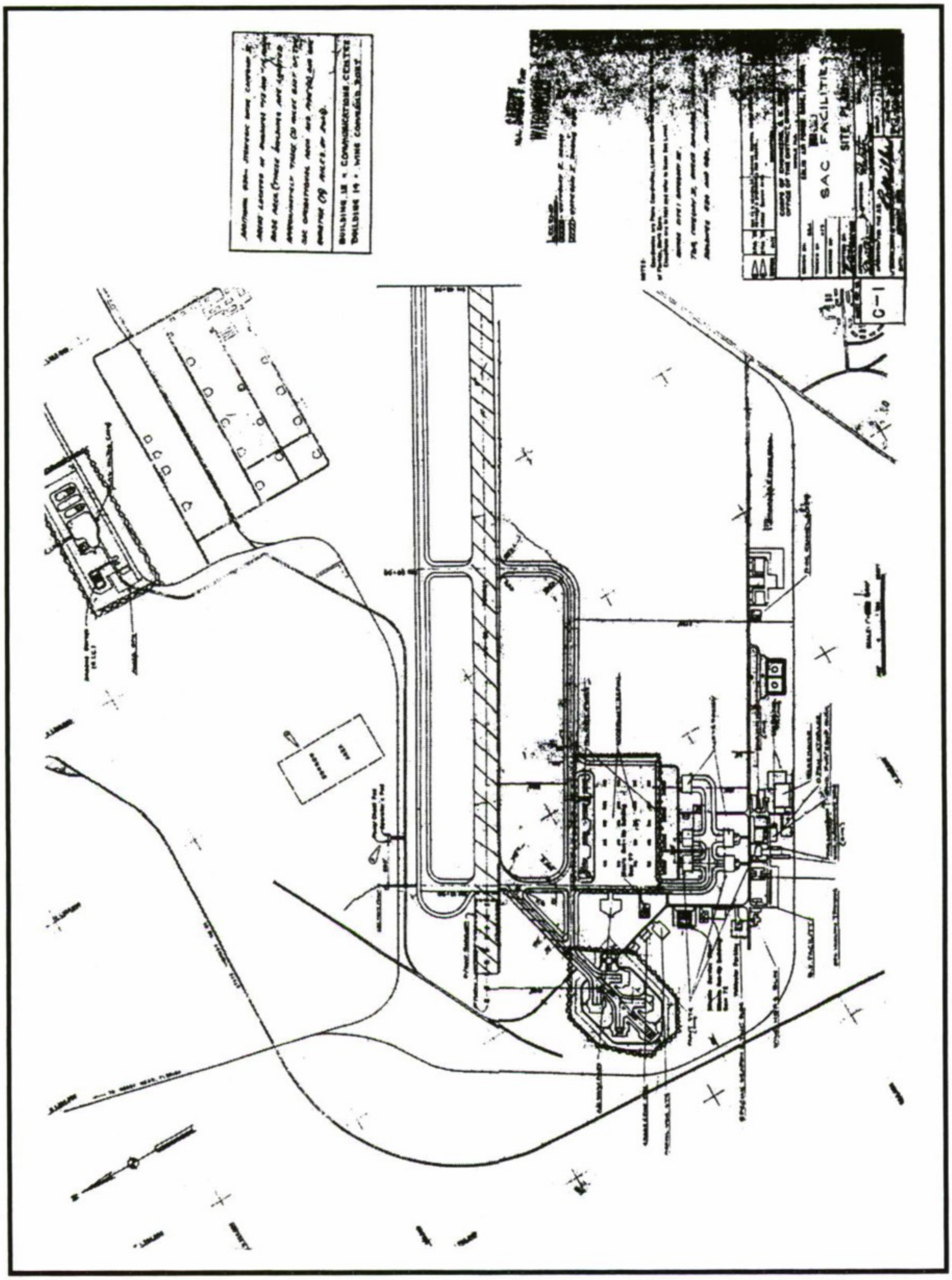

Plate 99: SAC Alert Area, Eglin Air Force Base. Site Plan, 1959. In *History of the 4135th Strategic Wing 1-30 June 1959.*

structures included a warehouse, an industrial building, and an operations building. The warehouse and industrial buildings appear to have conflated individual shops and the fire station, while the operations building combined squadron operations, intelligence, mission training, and wing headquarters (where appropriate). For example, the older armament and electronics shop was subsumed into the Industrial Building, while the Operations Building contained the SAC command post. The final SAC "cellular" concept was the reductive result of a civil engineering process of 1956-1958, with 13 of the 65 SAC alert areas (including the four installations sponsoring prototypes) scheduled to receive such construction in 1959. The Air Force contracted with the architectural-engineering firm Giffels & Rossetti of Detroit to develop the composite structures, with drawings completed in January 1959. Giffels & Rossetti had designed key Army munitions igloos during World War II. During 1958, the firm had the contract for Air Force-wide definitive drawings, and was in the middle of surveying the SAC alert bases of Lincoln (Nebraska), Biggs (Texas), and Westover (Massachusetts) and two ADC AC&W stations for "radiological fallout protection."[125]

The alert area at Eglin was too far along by spring 1959 to adapt completely to the SAC cellular plan, as had to be the case with several other tenant installations. Bases supporting SAC alert as a tenant included Amarillo, Dover (Delaware), Eglin, Grand Forks, Griffiss, K.I. Sawyer, Mather, McChord, McGuire, Minot, Otis, Robins, Selfridge, Seymour Johnson (South Carolina), Sheppard, Travis (California), and Wright-Patterson.[126] The command may have tried its cellular concept for the alert areas of some or all of the installations within this group. For example, SAC also erected the Squadron Operations and Target Intelligence Building, present at the Eglin SAC alert area, at Seymour Johnson and Griffiss from identical plans, yet replaced these structures with the more generic Operations Building at Robins and Wright-Patterson. Mather, Griffiss, K.I. Sawyer, Minot, Seymour Johnson, and Eglin all supported SAC Strategic Wings, with alert facilities under construction before the close of 1958—in advance of the cellular redesign for tenant SAC alert areas. Although not yet confirmed, it is likely that these SAC alert areas each had a Squadron Operations and Target Intelligence Building, a structure that was itself the beginning of a "composite" approach. The architect for the Squadron Operations and Target Intelligence Building of 1958 is tentatively identified as Giffels & Rossetti, the firm carrying out the full economizing design effort at the outset of 1959. SAC's General Purpose Aircraft (Repair) Shop as well as its Armament and Electronics Shop are both older standard infrastructure no longer built after 1958. The command incorporated them into the Industrial Building.

SAC alert compounds were further distinguished through the greater or lesser inclusion of segregated, secured special munitions structures, with assembly and checkout facilities, including that at Eglin. This situation first occurred for the Hound Dog / Quail weapons system. The supersonic Hound Dog (Guided Air Missile [GAM]-77) was an air-to-air guided missile, in research as of 1957, and placed at selected SAC facilities between 1959 and 1963. Specially modified B-52s carried the Hound Dog under their wings (Plate 100). The Hound Dog was the world's first nuclear-capable cruise missile and was part of a first-wave bomber mission preparatory for a second-wave full-scale attack. SAC planned to have its B-52s fire their missiles hundreds of miles from Soviet targets to destroy land-based enemy defenses. The Quail (GAM-72), a short-range missile, completed the package (see Volume II, Chapter 12). SAC intended that the Quail, carried in the B-52's bomb bay, divert Soviet fighter-interceptors away from the sequentially launched Hound Dogs. The Quail appeared on radar screens as a bomber, leading the enemy to assume that several attacks were in progress simultaneously. The Hound Dog / Quail was a relatively late addition in the SAC munitions arsenal, and as such, suggested that attack might include a provoked preemptive plan in addition to second-strike needs. As conceived, SAC alert focused on the nuclear and conventional bomb-dropping capabilities of its B-36s, B-47s, and B-52s.

Eglin's 4135th Strategic Wing was the first in the nation to gear up for the Hound Dog and the Quail,[127] in part fulfilling the weapons test and evaluation role of the Armament Center / Air Proving

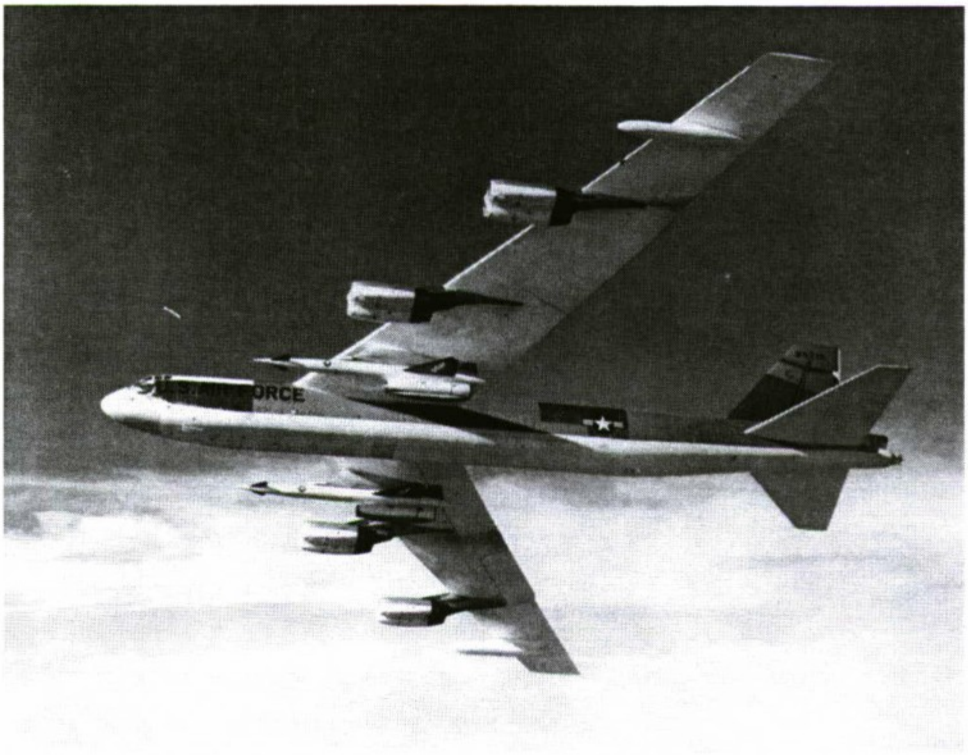

Plate 100: B-52 carrying Hound Dog Missiles, 1960. In *Semiannual Historical Report AF Plant Representative Office Boeing Airplane Company Wichita, Kansas 1 January – 30 June 1960.*

Ground under ARDC (and subsequently, AFSC). The wing was the first to receive the missiles, train with the weapons system, and air-launch the Quail (over the Eglin Gulf Test Range). The 4135th was also the first SAC wing to fire the Hound Dog from a B-52G on alert exercise and to stand "cocked" alert with the pair. In July 1958, the agency hired the Kansas City firm of Black & Veatch to design cubicle special munitions storage for the weapons system. By early 1959, the Air Force directed the Boston firm of Ganteaume & McMullen to design the run-up and service shops. Eglin's run-up and service shops were distinct from those of the rest of the nation due to the base's very early scheduled receipt of the weapons system. The Directorate of Installations authorized its South Atlantic Region to procure "special one-time drawings" for the run-up and service shops in 1958. Eglin's Hound Dog and Quail facilities, for example, used portable air-conditioning for the missiles and consoles in the service shop, rather than the permanent feature present in all other facilities nationwide. By mid-1961, the total Hound Dog – Quail budget had climbed to over $25 million, with construction still in progress.

Eglin began preparing for arrival of the Hound Dog and Quail missiles in mid-1959. The 54th Aviation Depot Squadron was in charge of missile storage and handling from June 1959 through June 1965. As of 31 July 1959, SAC supplied the 54th Aviation Depot Squadron with all the required technical publications for the Hound Dog. Approximately 800 pounds of classified materiel were at Eglin for the missile as of that date. Special weapons personnel moved into the SAC ordnance area in July, commencing training and calibrating test equipment. During this first month, 53 men from the 54th Aviation Depot Squadron trained for Hound Dog electronics at the plant of North American Aviation in Los Angeles. Ten men remained at Eglin to set up consoles and checkout during the period (Plate 101), while 37 men—all of whom had already completed factory training—integrated into the category II testing of the Quail over the Eglin Gulf Test Range. On 29 February 1960, the 4135th Strategic Wing fired the first operational Hound Dog from a B-52G (without live warheads).

Plate 101: Hound Dog Training Console, Wright-Patterson Air Force Base, 1961. In *History of the 4043rd Strategic Wing (SAC) 1 – 31 March 1961.*

The wing repeated this success in mid-April at the climax of a 10,800-mile, 22-hour exercise flight to the North Pole and back to Florida. Firing tested the reliability of the Hound Dog, simulating an alert. The exercise also tested aerial refueling of a B-52 loaded with two Hound Dogs, and the operation of bomber and missile guidance systems at –75 degrees Fahrenheit.

More tests continued at Eglin for the Hound Dog and Quail during the first half of 1960, which was critical for the SAC weapons systems program. An exercise on 21 April tested refueling of a Hound Dog-equipped B-52 enroute to the North Pole. KC-135 tankers from Westover Air Force Base in

Massachusetts handled the task. After turning at the Pole, the B-52 from Eglin flew back south, aerially refueled a second time over Lake Superior, headed for Key West, rounded the tip of Florida, and fired its two unarmed Hound Dogs over the Atlantic Missile Test Range off the coast from Patrick Air Force Base. On 26 April, a SAC bomber launched the fourth Hound Dog, over the Eglin Gulf Test Range. By the end of April 1960, the 4135th Strategic Wing had an inventory of seven Hound Dog missiles. Hound Dog and Quail missiles arrived at Eglin slowly. During May 1960, the Hound Dog inventory increased by four more missiles and the Quail inventory increased by two. A closed storage area for the Hound Dog was yet not available for the SAC special munitions. The situation prompted the 4135th Strategic Wing to request delay of further missile shipment. The Eighth Air Force at Westover Air Force Base denied the request, and augmentation at Eglin continued. In June, the 4135th Strategic Wing stockpiled 19 Hound Dogs and eight Quails. Fourteen B-52Gs were at the base. Of the missiles, nine of the Hound Dogs were operational missiles and 10 were test missiles. Three of the Quails were of operational type, while five were test. At this juncture, SAC did suspend delivery of the missiles due to storage problems. The Black & Veatch cubicle storage for the Hound Dog, added to the munitions compound for the base but segregated within it, consisted of two multi-stall igloos, checkout and assembly structure, independent water supply, and sentry post.[128] Hound Dog storage was under construction during 1959-1960. During June 1960, the 4135th Strategic Wing launched the first Quail by a SAC crew nationwide, again over the Eglin Gulf Test Range. As of August 1961 and March 1962, respectively, the Oklahoma City AMA at Tinker Air Force Base received the Hound Dog and the Quail missions. The Oklahoma City AMA served as the logistics manager for weapons system (see Volume II, Chapter 12). Tinker personnel completed modifications on the two weapons, also providing spares and ground equipment to the operational GAM-77 and GAM-72 squadrons.[129]

As of 1 July 1962, all 14 programmed Quail squadrons were combat ready, with 50 percent standing alert. Each Quail squadron possessed 31 decoy missiles, increased to 35 with the changeout from the GAM-72A to the GAM-72B during 1962-1963. As of 31 March 1963, all 29 programmed Hound Dog squadrons were combat ready, with 100 percent standing alert. By this date, SAC had purchased 425 Hound Dog missiles. Each B-52 alert squadron maintained 20 of the nuclear-tipped missiles, with 12 standing live alert (two missiles per bomber). SAC proposed buying another 386 Hound Dogs to augment its alert squadrons from 29 to 39, and to increase each squadron's missiles from 20 to 22. SAC also planned to upgrade the Hound Dog to the Skybolt (GAM-87), programmed during July 1961 and then cancelled in December 1962. As of the FY 1964 budget (autumn 1963), no more Hound Dog – Quail facilities remained in SAC programming. About 45 percent of the total SAC alert forces had the Hound Dog, while 21.5 percent had the Quail. Approximately 14 percent of the 65 SAC Strategic Wings on alert possessed both the Hound Dog and the Quail, with Eglin the very first of these.

At the outset of July 1959, the 4135th Strategic Wing at Eglin formally printed its SAC *Alert Plan*. Either Headquarters SAC at Offutt (Nebraska) or the Eighth Air Force at Westover (Massachusetts) had responsibility for calling alert for the Eglin wing. An act of sabotage, or an ADC warning, also initiated a SAC alert. The Emergency War Operations capability of the wing was in constant test to sustain preparedness for the actual conditions of war. Practice alerts and more extended exercises were a mainstay of the wing's activities. The 4135th Strategic Wing had operational procedures for a variety of conditions, including ones for a potential or actual nuclear accident on or near base (also known as a broken arrow alert). "Golden Hour" was a practice Eighth Air Force alert; "Team Play," a Headquarters SAC practice alert; "Golden Hour Tango," an Emergency War Operations scored test. Each component of the 4135th Strategic Wing had duties "at alert hour." During an alert, the support squadron for the wing was responsible for flying red alert pendant flags from conspicuous locations on base, including at least the wing headquarters (integrated on the main base at Eglin) and the squadron operations building. Alerts were of five escalating types: Alpha, Bravo, Coco, Romeo

(alternately known as Battle Cry), and Juliet (alternately known as Big Sickle). During Alpha, SAC required that its alert crews be ready to start their engines. For Bravo, the alert bombers were to be prepared to taxi and for Cocoa, to take off.

In May 1960, the 4135th Strategic Wing "increased its alert force from three, to four, and then to five crews and 'cocked' aircraft [B-52Gs]," following augmentation of international tensions. SAC-wide, the command ran the Top Rung exercise from May through July to evaluate all combat-ready B-47s and B-52s. The wing completed its nine Top Rung missions in early May. During June, the wing continued low-level training missions, flying 23 successful sorties, including ones using what were termed "the Fairball Juliet I and IV routes." SAC conducted 13 alert tests at Eglin in June, primarily Bravo—ground-readiness—alerts. The 4135th Strategic Wing also flew four B-52s in the SAC-wide Sky Shield exercise on 10 September 1960. Headquarters SAC selected only certain wings to participate in Sky Shield. The exercise was the most comprehensive test to date and involved Headquarters NORAD at Ent Air Force Base. During the exercise, the United States and Canadian governments grounded all civilian aircraft in the United States, Alaska, and Canada, and all aircraft within 150 miles of the continental coasts between 0600 and 1200 Zulu (Greenwich Mean) time—from 10pm to 4am on the West Coast and 1am to 7am on the East, with an equivalent synchronization in the time zones between. Sky Shield involved the entire radar, electronics, and fighter aircraft network. SAC B-52s flew as targets for the complex of NORAD defenses and brought the maximum possible number of units into play. After the missile crisis in Cuba of October 1962, Eglin's SAC wing slowly became less important, directly due to the prioritizing of SAC installations across the northern United States and to the emplacement of more and more sophisticated ICBMs. In February 1963, the 39th Bomb Wing replaced the 4135th Strategic Wing at the alert area. In 1965, SAC left Eglin, transferring the compound to TAC for air defense.

The 4137th Strategic Wing activated at Robins Air Force Base in February 1959 as one of three SAC alert compounds in Georgia: Hunter, with a 150-man molehole; and Turner and Robins with 70-man moleholes. SAC located its alert area on the northeast side of the base, away from all other installation functions. While the site provided sought-after security, the immediate terrain made construction difficult due to "nearly impenetrable Georgia swamps." Construction crews built up the former swampland with significant earthen fill.[130]

> In order to prepare the swampy area on the north end of Robins Air Force Base for construction, more than 700,000 cubic yards of muck had to be removed. The swampy area was then filled with good material to form a firm foundation for apron, runway, and structural construction. Drainage culverts were constructed of such magnitude that a good-sized automobile could be driven through them. In order to obtain adequate foundations, some of the buildings were placed on pilings.[131]

The SAC compound was similar to the one at Eglin and included a 70-man molehole, eight / nine-stub Christmas tree alert apron, rectangular refueling apron with four nose docks and one fuel system dock, operations building, industrial building, warehouse, Hound Dog and Quail run-up shops, combined Hound Dog and Quail service shop, two Hound Dog cubicle storage magazines, and Hound Dog checkout and assembly facility (Plate 102). SAC also used a maintenance building for the Hound Dog and Quail on the main base, unlike Eglin. Site plans for the Hound Dog / Quail facilities dated to late 1959.[132] Robins' SAC alert area is a good example of the continued fluidity of the SAC cellular concept at tenant locations. As at Eglin, Robins first planned for a combined operations and target intelligence building but unlike Eglin, the alert area for the 4137th Strategic Wing included the economy operations and industrial buildings in lieu of the older standard structures. The wing

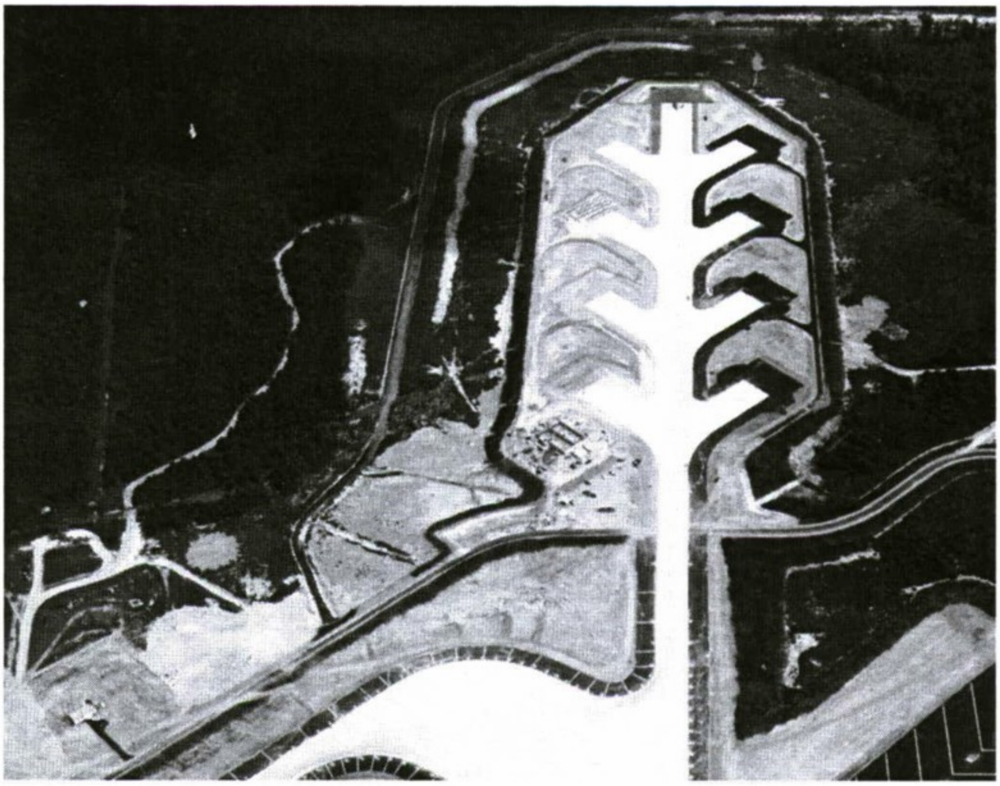

Plate 102: SAC Alert Apron, Robins Air Force Base, 1959. In *History of the Warner Robins Air Materiel Area 1 July 1959 – 30 June 1960.*

modified its operations building by enlarging its internal command post for activities during Emergency War Operations. The wing requested minor interior changes to the industrial building as well.[133]

Construction of the SAC alert area at Robins faced several challenges. Again, the anticipated arrival of B-52s necessitated extending the existing runway at the southeast end. The refueling and maintenance apron for the bombers and tankers covered 55 acres. This feature varied in thickness from 14 to 20 inches of reinforced concrete. Work did not begin on the Hound Dog and Quail special weapons storage structures until May 1960. SAC, as at Eglin, used existing World War II buildings on the main base for some of its administrative needs. Contractors completed the modifications to the Operations Building by late autumn 1959, then began on those for the Industrial Building and initiated construction for a warehouse in the SAC area. The command accepted the molehole at the standard cost of about $330,000 by the end of September.[134] While the molehole was in progress, SAC housed its Supply Directorate in a permanent-type warehouse on the main base three miles to the southwest of the alert area, also modifying an existing structure for use as a jet engine build-up shop. A final project on Robins proper was for a joint Air Materiel Command – SAC aircraft washrack and personnel decontamination center (Plate 103). As winter 1960 approached, the command encountered problems with the alert site. The floors in two nose docks were sinking which mandated a waiting period for repair until the next summer.[135] Nonetheless, by late January 1961, the 4137th Strategic Wing was participating in alert exercises. Also that spring, the wing joined in continued tests of NORAD, with these missions known as Big Blast. The first Hound Dog missile arrived at Robins on 21 February 1961, with eight of the missiles combat ready by the end of the month.[136] The first complementary Quail arrived on base in mid-May, with 20 on base by the end of July.[137] As the 4137th Strategic Wing became fully operational, modifications to the SAC alert area

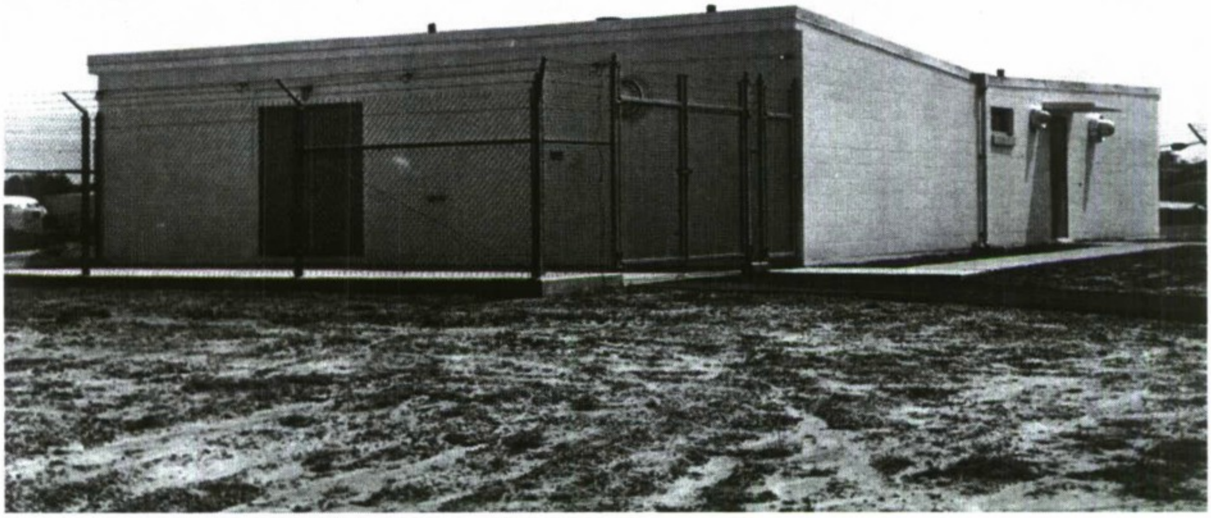

Plate 103: Joint SAC and Air Materiel Command Personnel Decontamination Center, Robins Air Force Base, 1961. In *History of the 4137th Strategic Wing (SAC) 1 February – 31 March 1961.*

continued. The command was especially dissatisfied with features of the economy buildings. In the case of the Industrial Building, SAC decided to construct an addition of 4,650 square feet to accommodate more traditional armament and electronics shops. By mid-1962, the wing had also completed a small annex to the Operations Building.[138]

As an Air Force installation in the Southeast, Robins went to a heightened status immediately during the Cuban missile crisis of 1962. On 19 October, SAC placed the 4137th Strategic Wing on alert. Eight B-52s went on ground alert, with one bomber flying a programmed scenario known as Hard Head VI. This situation lasted into 22 October, when SAC relieved the wing of its Hard Head VI commitment. Just before SAC implemented DEFCON 3 the same day, the 4137th Strategic Wing put their Sabotage Alert Plan into effect. Alert airmen went to a status of 12 hours on, 12 off. Airmen crews were rotating every eight hours before the day ended. Maintenance and support personnel went to 12-hour shifts as of 23 October. SAC deployed all high-security weapons packages (assumed to be Hound Dog missiles readied on B-52s) to temporary locations and left only one at Robins. As of 23 October, the command initiated the 4137th Strategic Wing's participation in Chrome Dome, a one-eighth airborne alert across SAC. Chrome Dome was a SAC war plan stepped up from the Hard Head configuration, executed in direct preparation for war with the Soviet Union. For the one-eighth airborne alert, the wing flew two aircraft per day along a preassigned southern route. KC-135 tankers supported the 4137th's B-52s for Chrome Dome, flying out of Westover in Massachusetts. The wing possessed 12 B-52 bombers and 11 KC-135 tankers at Robins at the outset of the Cuban crisis. (SAC had activated the 912th Air Refueling Squadron on base in December 1961.) On 24 October, SAC alert at Robins went to DEFCON 2. Chrome Dome flights returned to Robins, alternating with other aircraft. By 27 October, SAC flew three additional B-52s to the alert area at Robins, with another moved to the installation by the 31st. Men "cocked" the planes and prepared them for duty over a

period of 10 to 30 hours. Predictably, maintenance efforts on the B-52s and KC-135s stepped up during the height of the tension.[139] After the Cuban crisis, the 4137th Strategic Wing continued at Robins until February 1963, replaced by the 781st Bomb Squadron thereafter. The 64th Aviation Depot Squadron, responsible for the Hound Dog, remained at the installation into late July 1968. On 25 July 1968, both the 781st Bombardment Squadron and the 64th Aviation Depot Squadron deactivated. The 28th Bombardment Squadron continued a SAC mission at Robins for the remainder of the Cold War.

At Wright-Patterson, the 4043rd Strategic Wing activated in April 1959. Ohio supported three SAC alert compounds: at Lockbourne (150-man molehole), Clinton County (100-man molehole), and Wright-Patterson (70-man molehole) Air Force Bases. SAC built 24 structures to support its alert mission on base, including a number of small ancillary structures such as traffic check houses, water supply buildings, and backup power stations. The key infrastructure for SAC alert at Wright-Patterson included a molehole, large rectangular pen for parked aircraft, four nose docks, one fuel systems dock (added in 1961), operations building, industrial building, warehouse, Hound Dog / Quail service shop, Hound Dog and Quail run-up shops, two Hound Dog cubicle magazines, and Hound Dog / Quail checkout and assembly building (Plates 104-109).[140] SAC originally planned to build an eight-stub Christmas tree at Wright-Patterson, but instead settled for a simple rectangular parking apron. The warehouse was last among the structures constructed, underway late in 1960 (and anticipated as complete by November 1961). The 4043rd Strategic Wing, typical of SAC adjustments at individual installations where it was a tenant, also used existing space on base to support its mission. At Wright-Patterson, the primary structure adapted by SAC was the former readiness crew dormitory for the 56th FIS. This structure was immediately adjacent to the former ADC readiness-maintenance hangar, across the runway from the SAC alert compound. SAC set up its headquarters for the wing in the ADC dormitory until the operations building in the alert area became available.[141] Wright-Patterson accurately illustrated the SAC cellular concept. The Air Force erected the operations and industrial buildings, as well as the warehouse, directly from the standard designs by Giffels & Rossetti of January 1959 (see Plate 105). The molehole featured the corrugated tunnels to the underground floor, typical of a northern climate (see Plate 104). (Both Eglin and Robins used open ramps in lieu of tunnels.) Hound Dog and Quail structures were also standard, built from the 1958 designs of Black & Veatch and the 1959 designs of Ganteaume & McMullen (see Plates 106-107).[142]

As of January 1961, the 4043rd Strategic Wing was beginning to settle into its alert area. The wing moved from its temporary headquarters to the Operations Building that month, although it had been officially operational since July 1960. SAC planned to ship the first Hound Dog missile to Wright-Patterson in mid-March 1961, with the weapons system operational by June. While preparations went forward for receipt of the Hound Dog, airmen trained for the missile (see Plate 101) and SAC maintenance modified eight B-52s.

> Slung beneath the wings to the B-52, two GAM 77 Hound Dog missiles were scheduled to give the SAC bomber a triple-threat striking capability. The supersonic missile, with an effective range of hundreds of miles and carrying a nuclear payload, can act as a pathbreaker for the bomber or can itself deal a knockout blow to the primary target.[143]

SAC instituted training for the Hound Dog in the Hound Dog / Quail service shop (see Plate 106), including engine courses, missile crew chief courses, flight crew training, and, missile control and guidance training. The Hound Dog run-up shop (see Plate 107) was fully operational, with tasking for fuzing and arming the missile. SAC scheduled a North American Aviation team from Los

Plate 104: Leo A. Daly. 70-Man Molehole (Building 34004), Wright-Patterson Air Force Base, 1959. Photograph of 13 January 1960. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

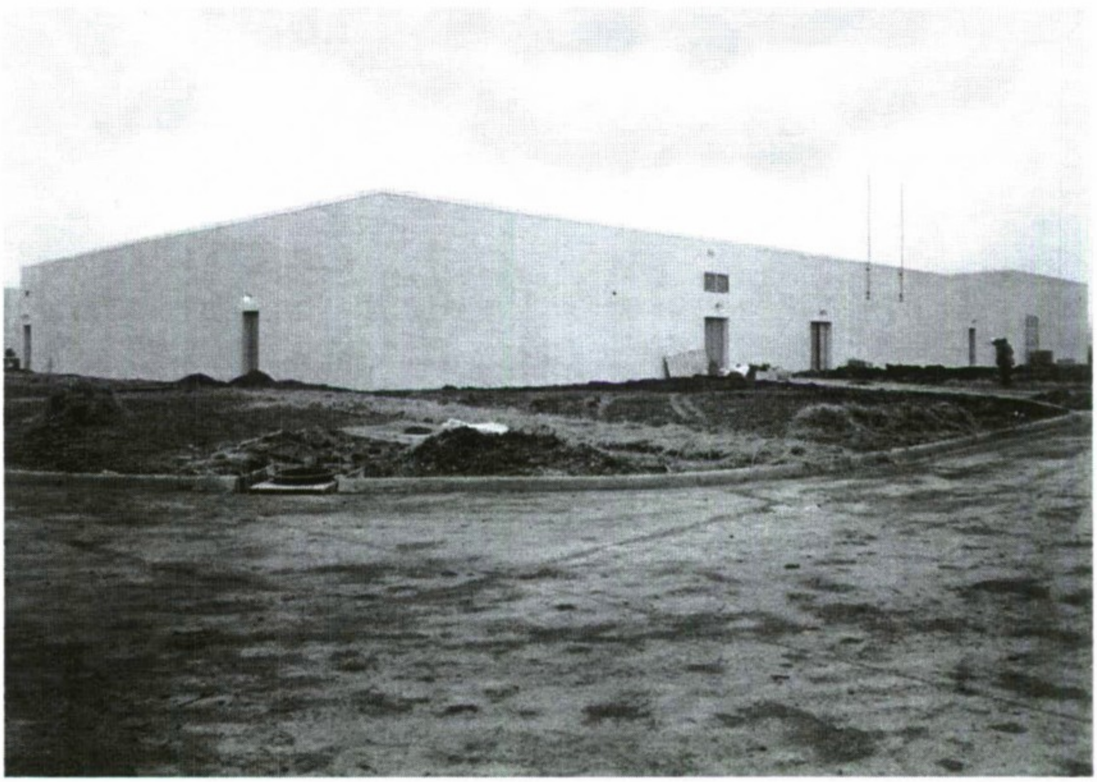

Plate 105: Giffels & Rossetti. Operations Building (Building 34010), SAC Alert Area, Wright-Patterson Air Force Base, 1959. Photograph of 14 January 1960. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

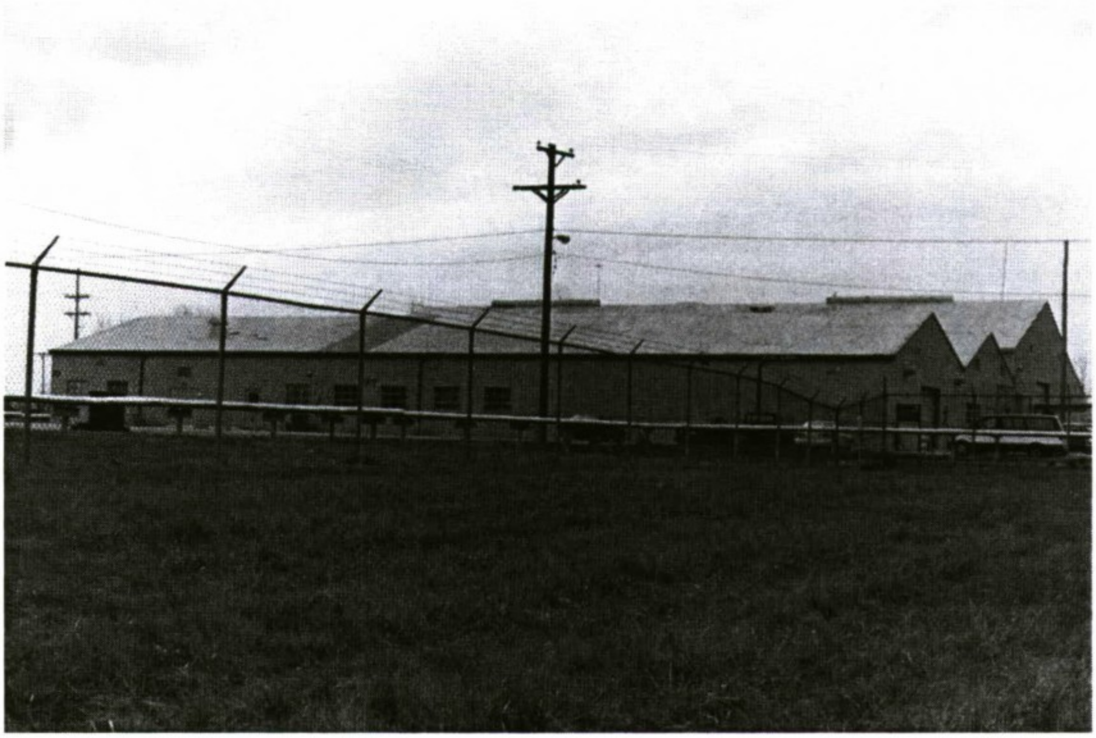

Plate 106: Ganteaume & McMullen. GAM-77 (Hound Dog) and GAM-72 (Quail) Service Shop (Building 34042), Wright-Patterson Air Force Base, 1959. Photograph of November 2000. K.J. Weitze for EDAW, Inc.

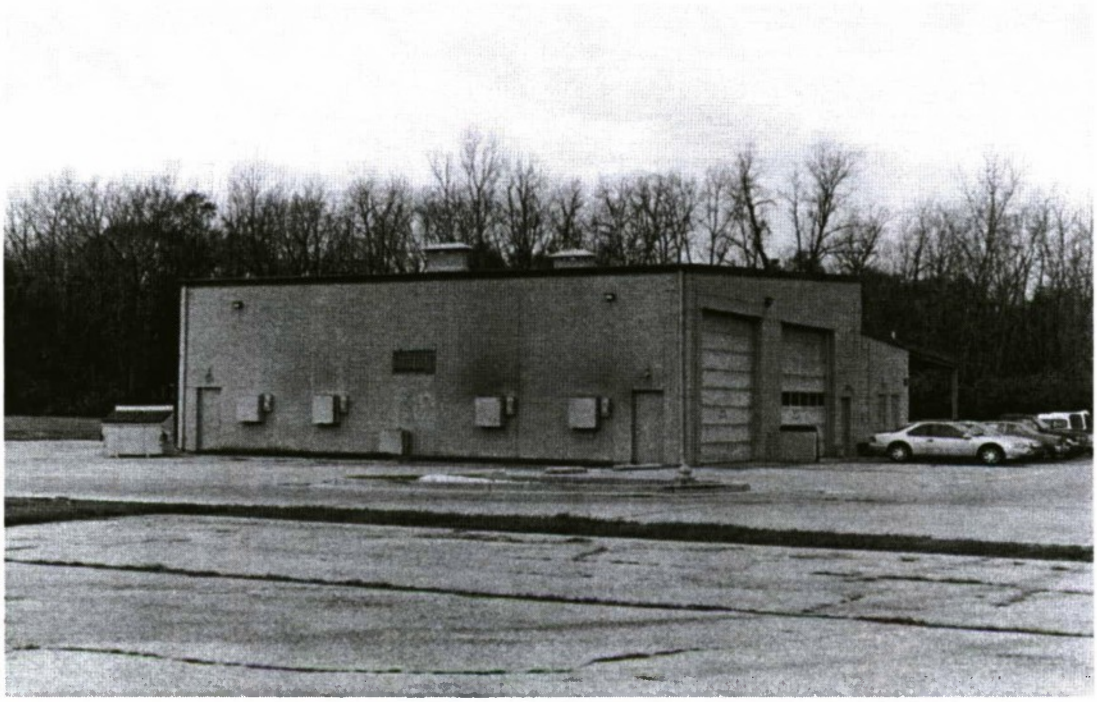

Plate 107: Ganteaume & McMullen. GAM-77 (Hound Dog) Run-up Shop (Building 34046), Wright-Patterson Air Force Base, 1959. Photograph of November 2000. K.J. Weitze for EDAW, Inc.

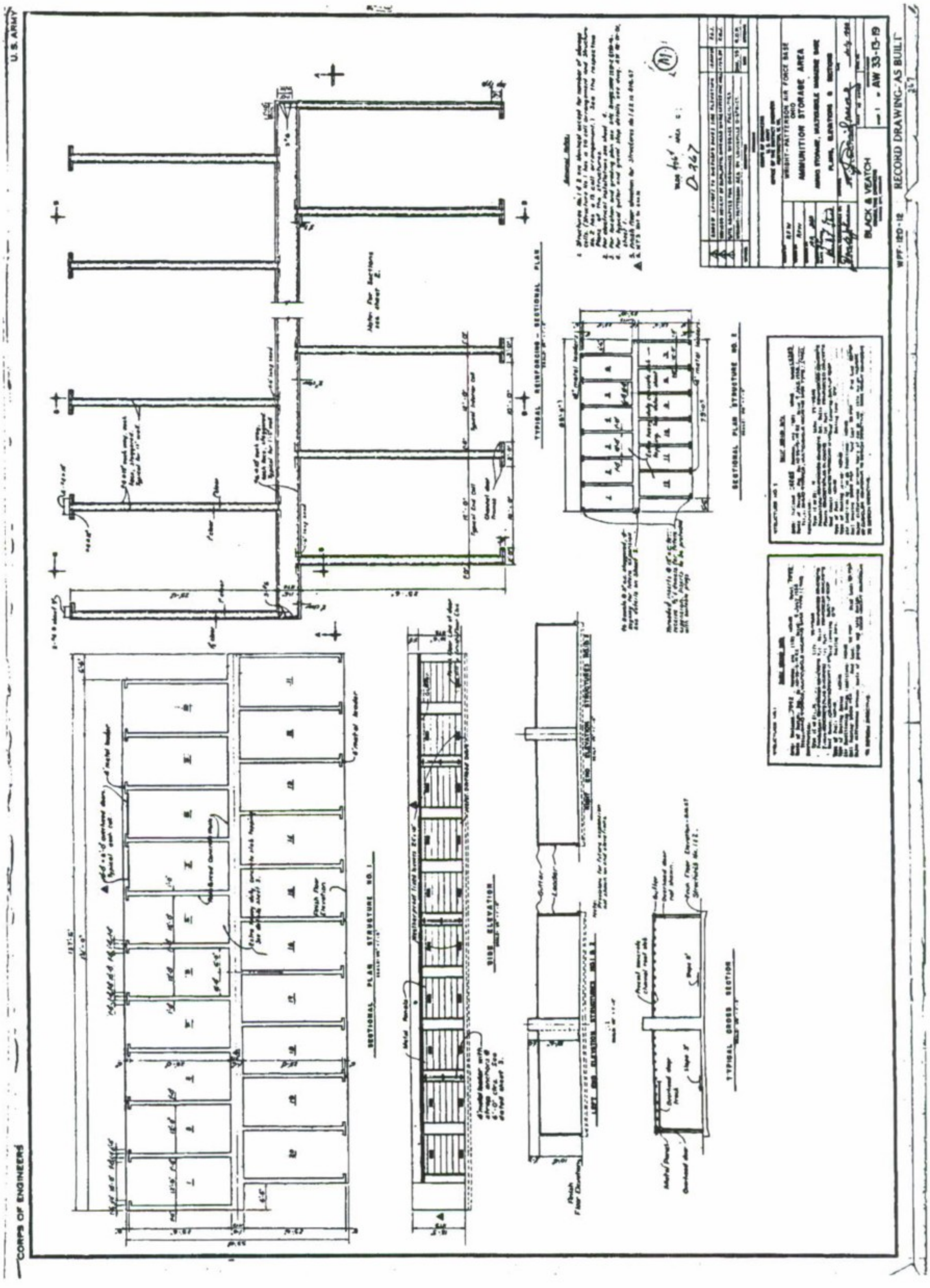

Plate 108: Black & Veatch. GAM-77 (Hound Dog) Multicubicle Magazine (Buildings 34062 and 34064), Wright-Patterson Air Force Base, 1958. Courtesy of Civil Engineering, Wright-Patterson Air Force Base.

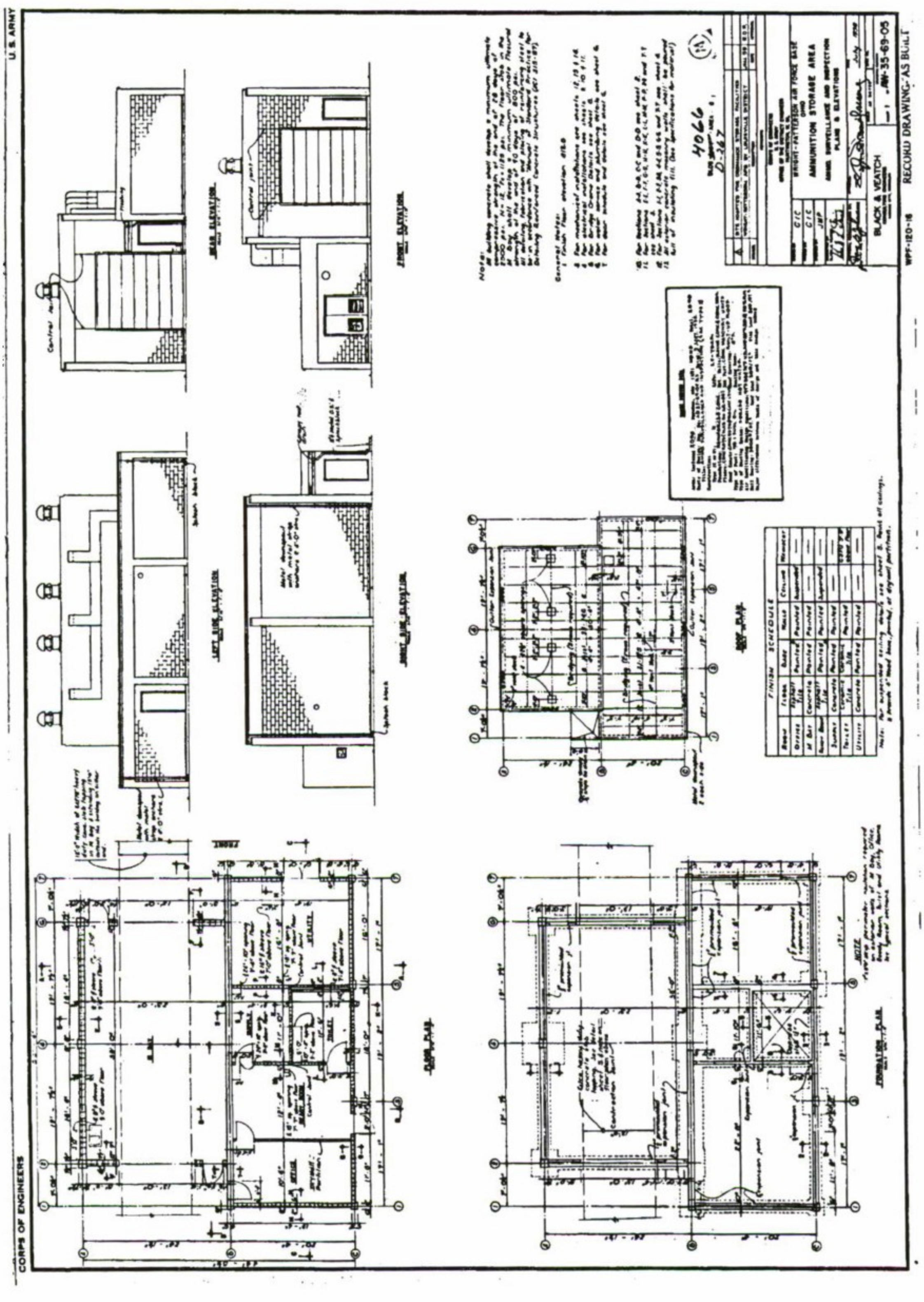

Plate 109: Black & Veatch. GAM-77 (Hound Dog) Checkout and Assembly (Building 34066), Wright-Patterson Air Force Base, 1958. Courtesy of Civil Engineering, Wright-Patterson Air Force Base.

Angeles to arrive at Wright-Patterson, along with the first missile, to run final maintenance checks for the weapons system.[144] The 4043rd Strategic Wing was responsible for the modified B-52s at the alert site, while the 922nd Air Refueling Squadron managed the KC-135s assigned to the installation. During January and February 1961, SAC instituted Hurry Home Oscar evaluation missions and Cover All practice airborne alert sorties. The 4043rd Strategic Wing sustained a "seven day on" alert cycle as it geared up, with men living in the molehole for the alert period (followed by an off period of a minimum of 3.5 days).[145]

As anticipated, North American Aviation delivered the first Hound Dog to Wright-Patterson in early 1961 aboard a C-124 and alert efforts intensified. Training for the missile continued, including trouble shooting at the black box and missile control panel level, repair of black boxes in the flight control and guidance systems, jet engine maintenance (of the 7,500-pound thrust power plant suspended in the pod below the missile), and test equipment operation (to verify the capabilities of individual missile components). Training courses lasted from eight to 240 hours.[146] The 4043rd Strategic Wing simultaneously ran both ground and airborne alerts "under realistic conditions." The wing launched its eight B-52s and 10 KC-135s as "follow-on sorties," with bombers and tankers to rendezvous in a "buddy" pattern. The 4043rd Strategic Wing possessed 12 B-52Es modified for the Hound Dog, with three of these further altered for the upgraded flight control panel for the GAM-77A. (SAC had temporarily grounded B-52G model bombers for modifications.) Airborne alerts stepped up SAC's precautions for war conditions to be a "deterrent force during periods of 'no guaranteed warning' against the growing missile threat." Twenty-four-hour airborne bombers were an insurance of SAC's retaliatory striking power.[147] The 4043rd Strategic Wing continued to receive its Hound Dog missiles slowly, with 12 in the inventory as of the end of October 1961.[148]

Headquarters SAC at Offutt Air Force Base directed the 4043rd Strategic Wing at Wright-Patterson to reinstate all aircraft alert sorties on 20 October 1962, the first indication to the wing that a crisis might be impending. SAC next directed an exercise that required the readying of two B-52s and two KC-135s for a Chrome Dome posture. Implementing DEFCON 3, the command raised readiness to an increased airborne alert on 22 October. The wing deployed its two Chrome Dome KC-135 tankers to the forward areas established at SAC bases in Moron and Torrejon, Spain. Early the morning of the 23rd, the first two Chrome Dome B-52 bombers departed Wright-Patterson. SAC went to DEFCON 2 on the 24th which required a recall of all personnel, with no further movement of aircraft until a briefing occurred. The wing prepared its aircraft, cocking bombers and tankers, after meetings in the command post within the Operations Building. The 4043rd Strategic Wing also had additional crews quartered in the Industrial Building in preparation for the emergency. All aircraft were on alert. As at Robins, Wright-Patterson received aircraft on loan, including a KC-135 deployed from Homestead in Florida. All routine training stopped and SAC suspended the weekly broken arrow exercise for the duration of the crisis. High alert ran for 10 days.

> From 22 October 1962 to 1 November 1962, Chrome Dome was launched daily as scheduled. DEFCON II became routine; schedules were established and aircrews rotated and briefed as required.[149]

As was true at both Eglin and Robins, the 4043rd Strategic Wing remained activated into February 1963, replaced thereafter by the 34th Bombardment Squadron until October 1975. The 66th Aviation Depot Squadron, responsible for the Hound Dog, deactivated at the end of September 1972.

Satellite Alert

A later version of alert occurred in the late 1960s into the middle 1970s, tied to the SAC concept of satellite basing. Satellite alert immediately followed a SAC Alert Posture Study of late 1966, and again focused on issues of survivability for its bomber and tanker forces. Even earlier, in about 1964,

SAC had increased its alert forces in some locations. At Griffiss, the 416th Bombardment Wing beefed up at its alert site. Six to eight bombers and eight to 12 tankers were on "called" alert during 1964-1966. These alerts were exercises of the Bravo and Cocoa type—the former involving engine starts only and the latter requiring movement of the aircraft to takeoff position. What appears to be different here is the sustained double alert. While selected SAC installations had both bombers and tankers responsible to strategic wings (such as at Robins and Wright-Patterson), only the bombers were on alert. The tankers flew as refueling backup during exercises. SAC returned to the use of alert trailers to accommodate the dual bomber and tanker alert configuration at single installations. At Griffiss, the 416th Bombardment Wing placed 15 four-bedroom trailers in two rows at the end of a rectangular pen in April 1964, with the alert apron and molehole across the runway. Alert tanker crews had to meet split and non-optimum launch conditions at the base.[150] Planning for satellite alert within SAC as of 1967 followed efforts such as that at Griffiss during 1964-1966. By 1968, the command also described its efforts as "permanent alert force dispersal."[151]

As of 30 June 1967, the SAC "primary alert system net" included 35 bases where the command was the host and 14 tenant bases. The network featured aircraft alert, ICBMs emplaced at or near installations, and other systems. There were 39 moleholes still in their original use—down from the 65 built only six years earlier. As of late March 1967, SAC planned to add 44 dispersal bases for satellite alert. This figure would increase SAC's full bomber-tanker alert capabilities to 83 locations and would surpass the pinnacle alert capabilities of the early 1960s. Twelve former SAC alert areas from 1958-1963 were among the 44 dispersal bases, including Bergstrom (Texas), Eglin, Forbes (Kansas), Hunter, Lincoln, McChord, McGuire, Mountain Home, Otis, Schilling (Kansas), Sheppard, and Walker (New Mexico). These installations came equipped with moleholes, ancillary support buildings, and often Christmas tree alert aprons. In addition, SAC identified Naval Air Stations, large and small city airports, contractor airfields, and other Air Force installations across the continental United States for the proposed program. Several bases within AFSC / AFLC were among the group: Edwards, Hill, McClellan, Palmdale (Air Force Plant [AFP] 42), and Tinker. SAC divided the potential dispersal / satellite alert sites into two groups: an "A" group with a tentative service date of July 1967 and a "B" group with an anticipated service date of January 1968. The A group included 17 locations, while the B group had 27.[152] SAC planning was far from set. Revisions and regroupings of the desired alert locations occurred almost immediately. In January 1968, SAC listed 41 dispersal sites. Of these, SAC looked at seven exclusively for the B-52, six for both B-52s and KC-135s, one for B-58s and KC-135s, one exclusively for B-58s, and 26 exclusively for KC-135s. As of this date, the AFSC and AFLC bases on the list were Edwards, Eglin, Tinker, and Wright-Patterson.[153]

SAC planning toward satellite alert continued in 1968-1969, with intentions to disperse 450 SAC aircraft (128 B-52s, 286 KC-135s, and 36 B-58s). The command specifically addressed the elevated threat from the Soviet sea [submarine]-launched ballistic missile (SLBM), as well as from increasingly accurate and destructive ICBMs. Numbers of potential dispersal locations dropped, and then climbed to 46 by the end of June. SAC added 11 new Air Force bases and deleted others—city and contractor airports were particularly reluctant to agree to SAC requests. The command began exercises under the name Glass Blade to test its plan for satellite dispersal. Headquarters SAC proposed its plan for dispersal of alert aircraft up through the Air Staff level, indicating that its "ultimate posture" was 70 satellite bases, including civilian fields. SAC recommended two bombers and two tankers as the ideal strike team at each satellite base, with the "only SAC function at the satellite base...maintaining the aircraft on alert." The proposed plan was "permanent dispersal."[154] The Air Staff approved Option I of the SAC 70-base plan in June 1968. Option I involved 26 satellite bases at military installations only, with 16 additional bases by mid-1970. SAC recommended a satellite operation at Homestead Air Force Base (with a preexisting molehole) as the first site, with eight other locations also prioritized.[155] Most of these sites had moleholes that SAC had built in the late 1950s (which were no longer in use for SAC alert), but in some cases the command proposed

new construction. At Whiteman Air Force Base, for example, SAC had a 150-man molehole but had never built a Christmas tree alert apron—instead using a rectangular alert pen. In 1969, Whiteman's master plan showed intentions for a new Christmas tree directly at the end of its major runway (which was never built).[156] SAC's planning for satellite alert in late 1968 listed locations in groups of one to eight, with actual sites still shifting. Eglin and Tinker were in the fourth priority group of April 1970. Wright-Patterson was in the fifth group of July 1970, while Kelly and McClellan were in the sixth group of January 1971.[157]

SAC was already speaking of economizing for its satellite basing needs by early 1969, paralleling the command's approach to the ancillary buildings that supported its moleholes of 1958-1961. Where the command required new infrastructure, SAC talked about a "composite building" that would be erected near alert aircraft. The composite building was a further reduction of the command's cellular concept of three basic structures—the operations, industrial, and warehouse buildings. For setup at Homestead, where SAC should have needed no new buildings, the command discussed siting for the future composite building, also shipping crew trailers from Plattsburgh Air Force Base in upstate New York for immediate reuse in Florida.[158] The original molehole was active as a Special Operations Facility. One of its functions in 1968 was as a waiting area for President Nixon enroute to his residence at Key Biscayne. Homestead, along with MacDill, was also a base that did not receive a Christmas tree alert apron in the late 1950s, instead relying on rectangular pens.[159] By mid-year, SAC also talked about "modular BAQs" (bachelor airmen's quarters). From the start, buildings for SAC satellite alert were to be simple, prefabricated structures. In its progress report of January 1969, SAC reviewed its surveys of priority sites. The costs for full construction at a military installation were about $550,000 to $600,000. These fell to less than $50,000 where the command could adapt a former SAC alert area (as at Forbes Air Force Base in Topeka). Again, not all preexisting SAC alert aprons and their compounds were available, even where they existed. At Eglin, the intent was to bear the full cost, which suggests that TAC would not vacate the alert area for a SAC return. More problems arose at other planned sites. Construction costs and lack of a suitable area at Edwards caused SAC to defer that installation from satellite base consideration. The command also interpreted the costs at Hill as very high (projected at $850,000), creating a deferral there as well. McClellan required resurvey and new programming documents. The possible use of Tinker was unresolved, but problematic. Although SAC intended to construct satellite facilities at both Eglin and Tinker, the command moved those two installations from 1969 planning to that for 1971. Kelly and McClellan remained tentative. By the June 1969 progress report, SAC discussed the satellite alert mission at Wright-Patterson as in conflict with a programmed MAC (Military Airlift Command) mission for the former alert parking ramp. SAC still had a bombardment wing on site, but was phasing it out.[160]

SAC satellite alert was a dispersal program that continued to change over time and was dependent on alert needs, availability of aircraft, and number of B-52-capable bases. The program shifted so quickly during the period when infrastructure was to go in place, that the early SAC satellite bases must have improvised to meet their needs. In July 1969, nine installations were operational for SAC satellite alert, with each having a main operating base at an existing SAC installation. The main operating base dispersed aircraft—ideally two B-52s and two KC-135s—to its satellite base. Satellite alerts were underway at Homestead (from Ramey—bombers), Sheppard (from Barksdale), Bergstrom (from Dyess [Texas]), Columbus [Mississippi] (from Blytheville [Arkansas]), Albany Naval Air Station [New York] (from Robins), Otis (from Griffiss), MacDill (from Ramey—tankers), Mountain Home (from Mather), and Whiteman (from Little Rock [Arkansas]). Of the nine, two dispersed only bombers (B-52s and B-58s, the latter from Little Rock), while three dispersed only tankers. Four SAC installations dispersed the goal of two bombers and two tankers together. The number of ground alerts shrank even as SAC established its satellite alert program, and by January 1970 the alerts at Sheppard, Bergstrom, Columbus, and Albany were running at only 50 percent (two aircraft at each installation). Mountain Home, Homestead, and MacDill also underwent reductions. Loring began using McGuire as a satellite base as a partial offset to these changes. Little Rock became a TAC base,

no longer able to disperse to Whiteman. Simultaneously, Little Rock also became a satellite recipient of dispersal from Barksdale, which was affected in turn by the rearrangement. The overall SAC satellite alert plan continued to program for 44 bases, with Boeing Field in Seattle, and Schilling and Larson Air Force Bases, still under consideration above this number.[161]

SAC satellite alert fluctuated again from July 1970 to June 1971 (during FY 1971). Satellite bases included Albany, Bergstrom, Columbus, Ellsworth (South Dakota), Homestead, Little Rock, MacDill, McGuire, Mountain Home, Otis, Sheppard, and Whiteman. Main operating bases were Altus, Barksdale, Beale, Blytheville, Carswell, Dyess, Griffiss, Lockbourne, Loring, March, Mather, McCoy, Ramey, Robins, and Westover. Several SAC operating bases dispersed both bombers and tankers to their satellite, as was the case for Robins to Albany.[162] Little is known about the program after this time period. SAC command-level documents for its satellite alert become unavailable between mid-1971 and the phaseout of the program in 1974-1975, due to their retained top secret classification. A satellite alert at Hill Air Force Base, however, does offer some information. The underlying design of the SAC satellite-alert infrastructure dates to about 1969-1970, nationwide. Buildings were minimal and included a composite squadron operations / dining building (for no more than 52 men) and prefabricated crew quarters (Plates 110-111). Drawings extant at Hill indicate that identical buildings went in for Campbell Air Force Station (Fort Campbell) in Kentucky in early 1970. The architectural-engineering firm responsible for the economy infrastructure was O. Germany, Inc., of Warren, Michigan.[163] The firm was not a prominent one, but did provide the Air Force with other prefabricated structures during this same period. (In July 1969, the firm designed a corrosion control facility for Wright-Patterson as Germany, Klees & Bliven.[164]) At Headquarters Air Force, the Directorate of Civil Engineering had formally decided by June 1970 that the SAC satellite basing program would use "modular relocatable structures." The Modular Relocatable Structures Program of the late 1960s into middle 1970s supported needs in Southeast Asia, including modular, prefabricated buildings such as dormitories, dining halls, hospitals, and chapels. SAC planned to purchase "12 modular relocatable structures 32' wide and varying in lengths from 90' to 120' at an estimated cost of $1.0 million through two step procurement" for its satellite basing.[165] The example at Hill illustrates both how the satellite program matured, and is indicative of the prominence of prefabricated construction for Air Force needs during the Vietnam War.

The Civil Engineering Center at Wright-Patterson (see Volume I, Part III) had the responsibility for contracting the prefabricated buildings required by SAC for its satellite alert, which also supported the use of a Detroit firm for their design and engineering. Prefabricated buildings were a very high priority for the Civil Engineering Center during the Vietnam War, with significant prototype testing for individual structures and for the Bare Base concept at Eglin's auxiliary field 2 (see Volume II, Chapter 4). The SAC program continued to insist on economy.

> Austerity is one of the key factors of the SAC Satellite Basing Program...All new buildings will be modular / preengineered relocatable structures. The modular relocatable buildings for crew quarters will be procured by the Civil Engineering Center at Wright-Patterson AFB [Air Force Base], Ohio...These buildings must be repetitive and / or extendable to satisfy varying scopes.[166]

SAC planned for a satellite alert facility at Hill as of April 1971. The base newspaper announced that Hill was to be one of six satellite alert bases for SAC, at least several of which would receive new infrastructure and selected apron reconfigurations. The six installations were Grand Forks, Hill, K.I. Sawyer, McConnell, Minot, and Whiteman.[167] Of these bases, Grand Forks, K.I. Sawyer, and Minot had not appeared previously on SAC programming lists. Only Whiteman, among the group, was already functional in interim satellite alert status. Both files and drawings at Hill indicate that as of mid-December 1970 SAC planned for one composite building, three prefabricated crew quarters, and

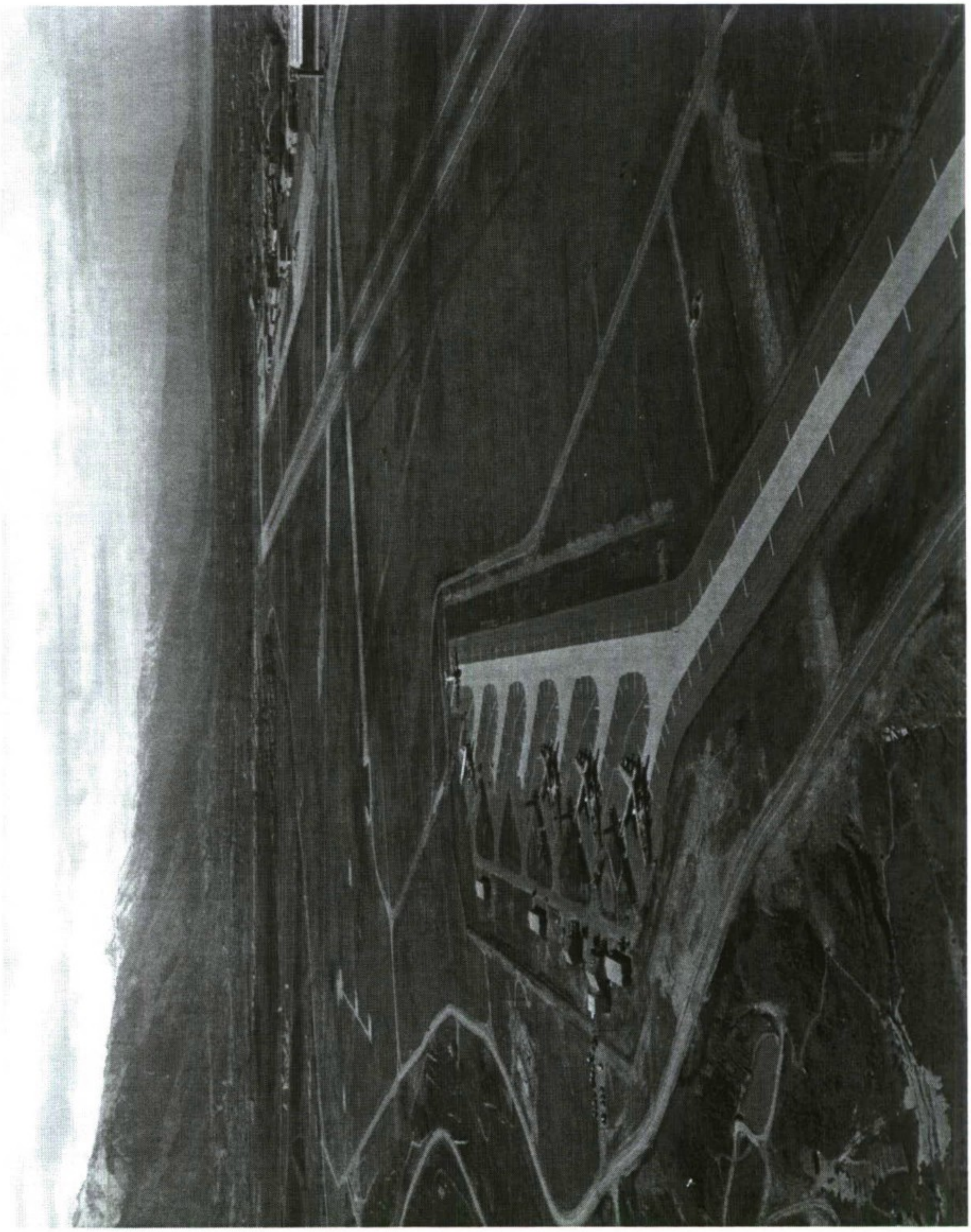

Plate 110: SAC Satellite Alert, Hill Air Force Base, 1974. Courtesy of the History Office, Hill Air Force Base.

Plate 111: O. Germany. SAC Composite Building and Crew Quarters (Buildings 772, 773, 774, 777, and 778), Satellite Alert, Hill Air Force Base, 1974. In *History of the 456th Bombardment Wing (Heavy) April – June 1974*, volume 1.

a seven-stub Christmas tree alert apron—with infrastructure in progress as of July 1971. Costs had more than doubled from estimates of early 1969 and took the project to over $1.5 million.[168] The dispersed SAC aircraft were to include four B-52s and two KC-135s from the 456th Bombardment Wing at Beale Air Force Base, located north of Sacramento. The 456th Bombardment Wing had previously participated in SAC satellite alert by dispersing to Mountain Home in Idaho during 1970-1971. The wing had dispersed to Castle Air Force Base in central California while construction was underway at Hill in 1972. Satellite alert was a rotational duty, with 14 days at the satellite base followed by a crew return to Beale. From the beginning there were challenges during the construction of the satellite alert facility at Hill. The runway was narrow for B-52s, space for SAC weapons storage was not readily available, and at least 15 percent of the time alert crews would not be able to take off quickly enough to achieve the standards of the SAC Emergency War Operations plan (due to winter ice). By late 1972, the situation was little changed.[169]

The Hill satellite alert area faced more problems throughout 1973, with activation delayed until the height of winter.[170] SAC placed three trailers near the composite building until the prefabricated crew quarters were ready.[171] On 27 December 1973, the 456th Bombardment Wing, Detachment 1, flew the first B-52 to Hill. Four bombers were on alert as of 1 January 1974, with a 28-day alert cycle for the aircraft. At the end of each period, four new B-52s replaced those on alert, with those at Hill returning to Beale. The alert crews changed out every seven days.

> On Thursday of each week, four fresh crews from Beale replaced the four crews which had been on alert all week, and twelve fresh maintenance personnel from Beale replaced the twelve which had been at Hill the previous week.[172]

A handful of Air Force personnel from the 456th Bombardment Wing sustained permanent duty to Hill. Weapons issues dominated remaining concerns. SAC added the SRAM, with nuclear warhead and inertial guidance, to its arsenal at the time of satellite alert. The SRAM, like the MB-1 Genie for ADC and the Hound Dog for SAC, was a guided missile that needed special storage. As was true for the MB-1 and the Hound Dog, Black & Veatch designed cubicle magazines and a checkout and assembly structure for the SRAM—the typical infrastructure to be anticipated for SAC satellite alert. At Hill, SAC did not build SRAM structures, but instead downloaded the nuclear weapon from a B-52 going off alert and immediately uploaded it onto the plane going on alert. Problems arose, however, when SAC downgraded an aircraft from alert and required a MAC transport of the SRAM back to Beale. The SRAM sat outside without a special storage structure while awaiting transport.[173]

Although the numbers of SAC satellite alert compounds built during 1971-1973 are not fully researched here, a pattern does emerge. At Grand Forks, K.I. Sawyer, and Minot Air Force Bases—where both moleholes and alert aprons from the late 1950s already existed—SAC chose to build secured, quasi-rectangular parking pens ringed by five to six prefabricated crew quarters, each standardized through the O. Germany design of 1969-1970. At K.I. Sawyer and Minot, the rectangular pen accommodated tankers on satellite alert, while the adjacent Christmas tree and its molehole handled satellite bombers. The molehole appears to have functioned in lieu of the composite building, providing space for crew quarters as well as dining and operations briefings. At Grand Forks, SAC reconfigured the preexisting 90-degree stub alert apron as a secured rectangular pen, surrounded it with the modular crew quarters, and used the molehole for a mess and squadron operations. The prefabricated crew quarters, like the trailers at the outset of SAC alert in 1958, sat next to their planes.[174] Efforts at Hill seem particularly austere due to the fact that no SAC infrastructure from the late 1950s period of alert existed on site, leaving a landscape of only the single composite building and three modular crew quarters (see Plate 111).

The SAC satellite alert basing program faced more and more problems. The Directorate of Civil Engineering cancelled the two-step procurement of the modular relocatable crew quarters as of February 1972 "after reevaluation of the technical difficulties and cost of modular relocatable construction vs. permanent construction techniques."[175] While the Air Force shipped and erected limited numbers of the modular crew quarters during 1971-1973, no more units were forthcoming once SAC had exhausted the available supply in storage. By mid-1974, SAC blamed the "austere approach" but regardless of that, "new problems were surfacing as fast as solutions for the old ones were being found."[176] Morale was a top problem for the men, with the temporary duty assignment unacceptable to many. The Fifteenth Air Force established a study group for its SAC satellite and main operating bases, including the satellites at Hill, Bergstrom (from Dyess), Glasgow [Montana] (from Fairchild), Roswell, New Mexico [at the former Walker Air Force Base] (from March), and Mountain Home (from Mather).[177] The SAC satellite alert program continued to falter, and by autumn 1974 the command began to deactivate a number of the locations from alert (keeping them for dispersal missions). As of January 1975, only 13 satellite alert bases were to remain, with four main operating locations. By July 1975, pure satellite alert was to be in place at only nine sites, with three main operating locations.[178] SAC satellite alert at Hill deactivated in 1975 after approximately one year of operational status.[179]

Infrastructure for Specialized Use: The Double-Cantilever Hangar

The double-cantilever hangar of 1951 was an important SAC structure originally designed and engineered to accommodate the B-36 and typically found as a maintenance facility on the command's installations. The hangar exists at five of the ARDC and Air Materiel Command bases addressed in this study, but in each case was in specialized use. Between 1951 and 1955, the Air Force erected approximately 55 double-cantilever hangars at about 46 installations in the United States and

overseas. The structure offered a large area of clear span by using cantilevers in two directions and incorporating shops in interior towers. Kuljian Corporation, of Philadelphia, designed the 1951 hangar for the Army Corps of Engineers. Kuljian received specifications from the Corps after an aborted attempt to design the needed hangar through an earlier firm. SAC undoubtedly worked with Air Materiel Command on the baseline specifications, although there is not yet a full understanding of the initial design. Kuljian developed the double-cantilever hangar in five variations as requested by the Air Force: the HB (heavy bomber), MB (medium bomber), X-1 (basic version, expansible), X-2 (MB, expansible), and X-3 (HB, expansible). Each of the versions was a large hangar. The HB or X-1 (essentially the same structure, with the X-1 allowing for later expansion) could house two B-36s: nose to nose, or tail to tail, with the greater part of the bomber enclosed within the hangar for maintenance. The MB or X-2 could accommodate four B-36s, while the X-3 could handle six of the oversized bomber. Footprint size of the hangars was 250 by 250 feet (for the HB and X-1), 350 by 250 feet (for the MB and X-2), and 600 by 250 feet (for the X-3)—with slightly different dimensions for the expansible versions. The double-cantilever hangar was alternately known as a DC hangar, widely interpreted in the engineering community as a major achievement.[180]

The Air Force erected double-cantilever hangars for ARDC and Air Materiel Command at Edwards, Eglin, Hanscom, Kirtland, and McClellan Air Force Bases. Only in the case of Kirtland was the hangar tied directly to a sustained SAC mission, although the hangar at Edwards specifically supported maintenance and repair for testing programs related to the B-36. (At McClellan, a B-36 modification mission was short-lived, and primarily used World War II hangars on base.) At Kirtland, SAC required three double-cantilever hangars, with construction of the first in 1951 and with the two following immediately in 1952 (Plate 112). While sometimes double-cantilever hangars

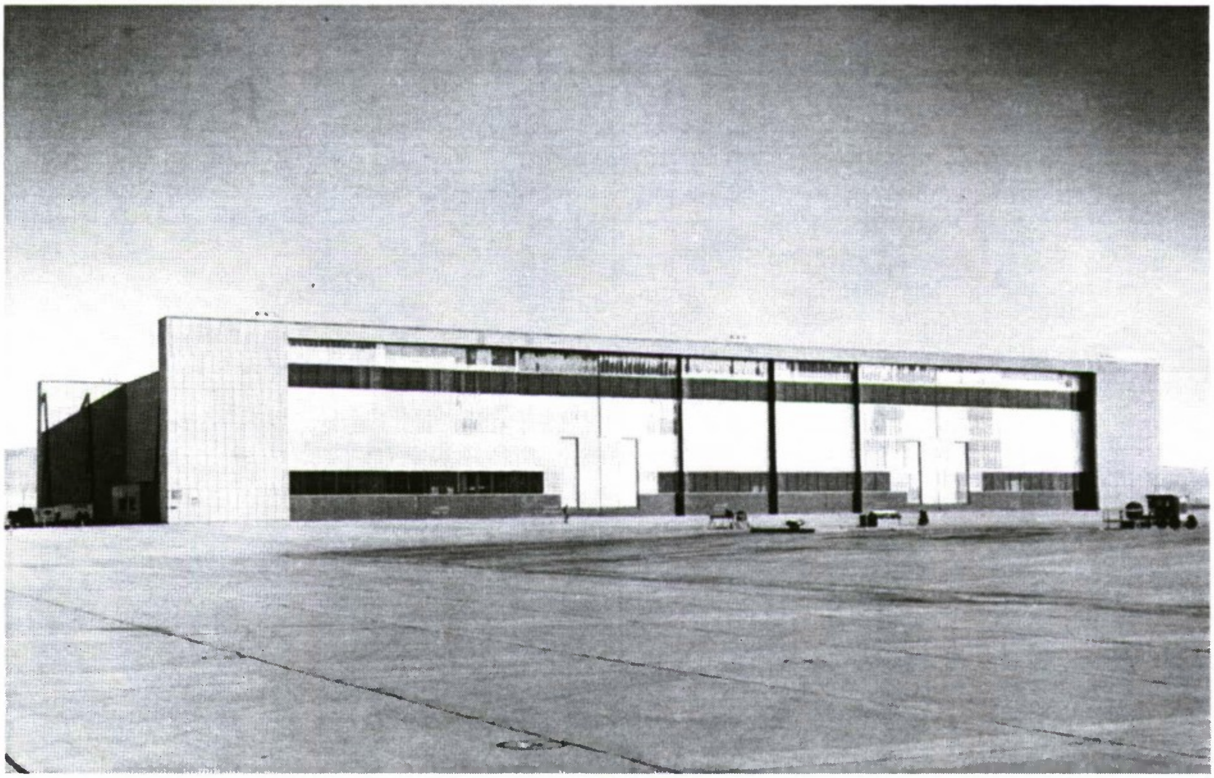

Plate 112: Kuljian Corporation. Double-Cantilever Hangar (Building 1003), Kirtland Air Force Base, 1952. Photograph of 1955. In *History of the Air Force Special Weapons Center 1 January – 30 June 1955.*

are found paired at important early 1950s SAC bases (such as Lincoln in Nebraska and Goose in Canada), the presence of three is unique. The 1951 double-cantilever hangar at Kirtland, in addition, is of transitional type with special bridge trusses engineered for the hangar by the Pacific Iron and Steel Company of Los Angeles. SAC erected only one other such hangar (in the largest version accommodating six B-36s), at Nouasseur Air Base in Morocco (see Volume II, Chapter 8). The flanking two Kuljian double-cantilever hangars at Kirtland, while standard, were among the very first erected anywhere. Each of the three Kirtland hangars is an MB structure, capable of handling four B-36s—offering workspace for 12 B-36s simultaneously. The initial SAC mission for the B-36 at Kirtland was modification and fitting for the atomic bomb, and support of testing at the Nevada Proving Ground and in the Marshall Islands. The remaining four double-cantilever hangars at Edwards, Eglin, Hanscom, and McClellan are the basic version, with one hangar at each base. In every case, the Air Force erected the hangars in 1953-1955 during the height of the buildout for the maintenance structure. Only at Edwards did the Air Force intend that the hangar accommodate the B-36, with a runway built for the aircraft. At Eglin, TAC used the double-cantilever hangar at Hurlburt Field for its fighter aircraft (not uncommon at selected TAC bases and airfields). At Hanscom, the hangar functioned as maintenance for a variety of planes, with the B-29 the largest. At McClellan, the hangar supported the 552nd AEW&C Wing.

Large Phased-Array Radar and the Space Tracking Mission

Large phased-array radars were initially a phenomenon associated with the technologies required by the advancing Cold War of the 1960s.[181] Continuous progress in radar had occurred since World War II, with Air Force R&D focused at the RADC at Griffiss and the laboratories at Hanscom. ARDC prototype-tested many of the sequential radars on the ranges at Eglin (where the command would oversee the construction of the first large phased-array radar between 1960 and 1969). For long-range advance warning, ADC had established a series of radar lines between 1951 and 1958 that were successively tiered above the American – Canadian border. These radars looked for enemy aircraft. Between late 1951 and 1954, more than 30 radars also had gone in place south of the border (the Pinetree Line). Following Pinetree, scientists at McGill University in Montreal and MIT's Lincoln Laboratory at Hanscom had developed an aural presentation for radar, whereby aircraft flying into range would set off an alarm. The aural radar fence, known as the Mid-Canada Line or McGill Fence, was not sophisticated in its ability to screen, but did not require manning. The Pinetree and McGill radar fences had overlapped in their construction. Desire to build a fence above the Arctic Circle across Alaska and Canada next led to the DEW Line, with the first outpost on Barter Island off the northeast coast of Alaska in 1953. Atmospheric conditions in the far north made yet another network necessary: the White Alice Communications System (WACS) of 1956-1958. WACS stood up to severe weather and Northern Light disturbances by using forward propagation tropospheric scatter to establish communications over very long distances. The WACS and DEW Line augmented AC&W radars, effectively creating the northernmost radar fence and a workable system in Alaska. Between 1956 and 1961, the Air Force also extended the DEW Line, both east and west. DEW East, for example, extended the radar line 1,200 miles from Cape Dyer, Baffin Island, to Keflavik, Iceland. Its program management involved both ARDC and Air Materiel Command, with a project office at Hanscom. DEW East's domestic test site for its AN/FSP-30 radar was Eglin, at a simulated ice cap site built there in the late 1950s. ADC subsequently adapted the AN/FPS-30 as a training facility[182] (see Volume II, Chapter 4). Each of these programs set the stage for work on missile search-and-detection radar, and soon on large phased-array radar.

While ADC upgraded its AC&W radars with improved equipment for SAGE during the late 1950s and early 1960s, air defense realities shifted from enemy aircraft to ICBMs. The next radars marked an important turning point in R&D. The Ballistic Missile Early Warning System (BMEWS), an Air Force program managed through Hanscom's Electronic Systems Division, provided the first

operational intermediate-range ballistic missile (IRBM) and ICBM warning. Contractors for the RADC developed studies for the BMEWS radars that were critical to the final effort. The system used two radars, the AN/FPS-49 tracking radar and the AN/FPS-50 detection radar.[183] Three BMEWS radar stations were under construction as of 1958. The Thule, Greenland, facility was operational in late 1960; that at Clear, Alaska, in mid-1961; and, that at Fylingdales Moor, England, in autumn 1963. These radars combined the functions of earlier ones and introduced a much higher level of detection sophistication. The AN/FPS-49 and AN/FPS-50 were also physically large, as would be true for the phased-array radars to come. The AN/FPS-49 was a mechanically-steered radar that featured an 84-foot parabolic dish antenna sheathed in a radome. The AN/FPS-50 was a fixed-fence radar that stood 165 feet tall and 400 feet wide and functioned through line of sight. By 1958-1960, radar electronics engineers began to understand that phased-array would define the next generation of modern military radar.

Large phased-array radar is distinguished from its predecessor generation of radars in both its purpose and its basic method of operation. The large phased-array radar could interpret dynamic objects at a great distance, and thus could be used for missile warning and space tracking. The mid-to-late 1950s was a period of significant advancement for radar, in both the Soviet Union and the United States. Coming on the heels of Sputnik, American military analysts discovered a Soviet system of very large radars—so large, that at first the infrastructure was thought not to be radar. Between 1955 and the early 1970s, the Soviet Union is assumed to have built 11 of these radars—nicknamed the Hen House radars by American analysts—around the periphery of the Eurasian land mass. In counterpoint, the Air Force erected BMEWS and initiated efforts toward more sophisticated long-range tracking. The United States Army simultaneously worked toward operational large phased-array radars for ballistic missile defense. From the beginning, the Air Force and Army efforts were related to one another, with advancements in one arena contributing to its complement. The RADC had contracted with the Radio Corporation of America (RCA) and General Electric in developing BMEWS. At the same time, the RADC initiated efforts toward the AN/FPS-85 that AFSC would erect at Eglin.[184] The RADC erected the prototype for the BMEWS radar at its Trinidad test site off the coast of Venezuela in 1958 and considered the site for the location of the AN/FPS-85 as well. The Trinidad site was 2,000 miles down range from the ICBM launch sites at the Air Force Missile Test Center at Patrick Air Force Base (with launch sites physically located at Cape Canaveral Air Force Station to the north). Air Force radars in Trinidad tracked and analyzed missile flights across the Atlantic Missile Test Range, helping the Air Force "construct an effective shield against the threat of ballistic missiles." The Trinidad BMEWS prototype radar (Plate 113) gathered data on missiles, satellites, and meteors for ARDC, as well as sustaining its proving ground role for the RADC. In December 1961, AFSC charged the RADC with developing a sensor for the 496L Space Track System. The L-System program offices were at Hanscom within the Electronics Systems Division.

The Air Force planned Project 496L as a network of both radar and optical sensors for "detecting, tracking and cataloging all man-made space objects." The project, known as SPADATS (Space Detection and Tracking System) and initiated as Project Spacetrack under the Cambridge Research Center in November 1957 following Sputnik, evolved into a full-scale satellite and space debris tracking effort. In 1958, the Advanced Research Projects Agency (ARPA) tasked the Air Force with "handling tracking data obtained by all other DoD [Department of Defense] agencies and for publishing a catalog of all objects in orbit, listing their positions for every instant of time throughout the world." The next year Project Spacetrack became Project 496L, with the intention of developing an operating system to manage the sophisticated tracking required for ADC. During 1959, the Electronic Systems Center also erected a training spacetrack control center at Hanscom, dedicating the facility in February 1960. (AFSC generically referenced the center as a Data Analysis Laboratory.) ADC began sending personnel for its first satellite tracking unit to the National Space Surveillance Control Center at Hanscom by late in the year (Plate 114). The command planned its

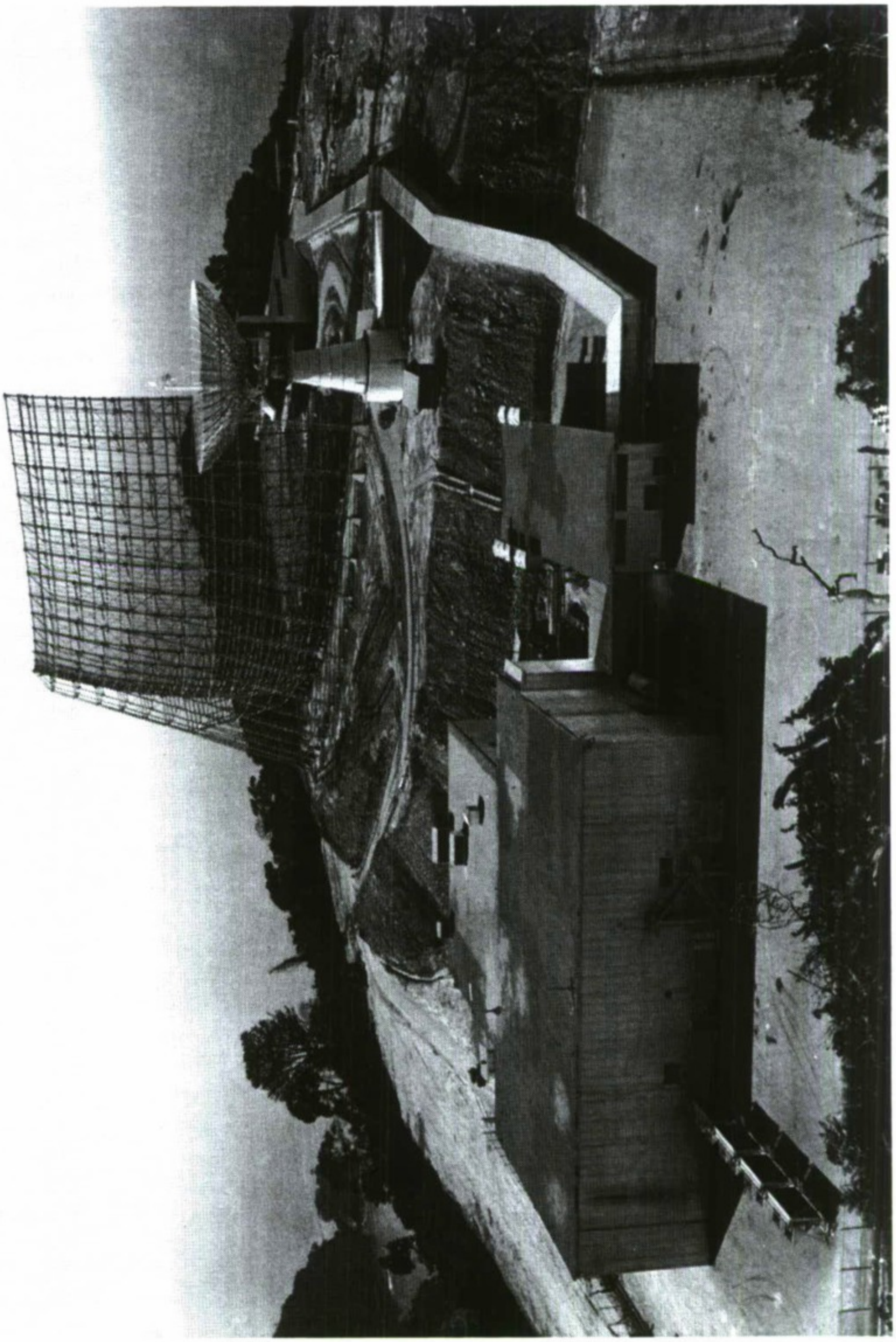

Plate 113: BMEWS Prototype Radar Site, Trinidad, 1958. Courtesy of the History Office, Rome Research Site, AFRL.

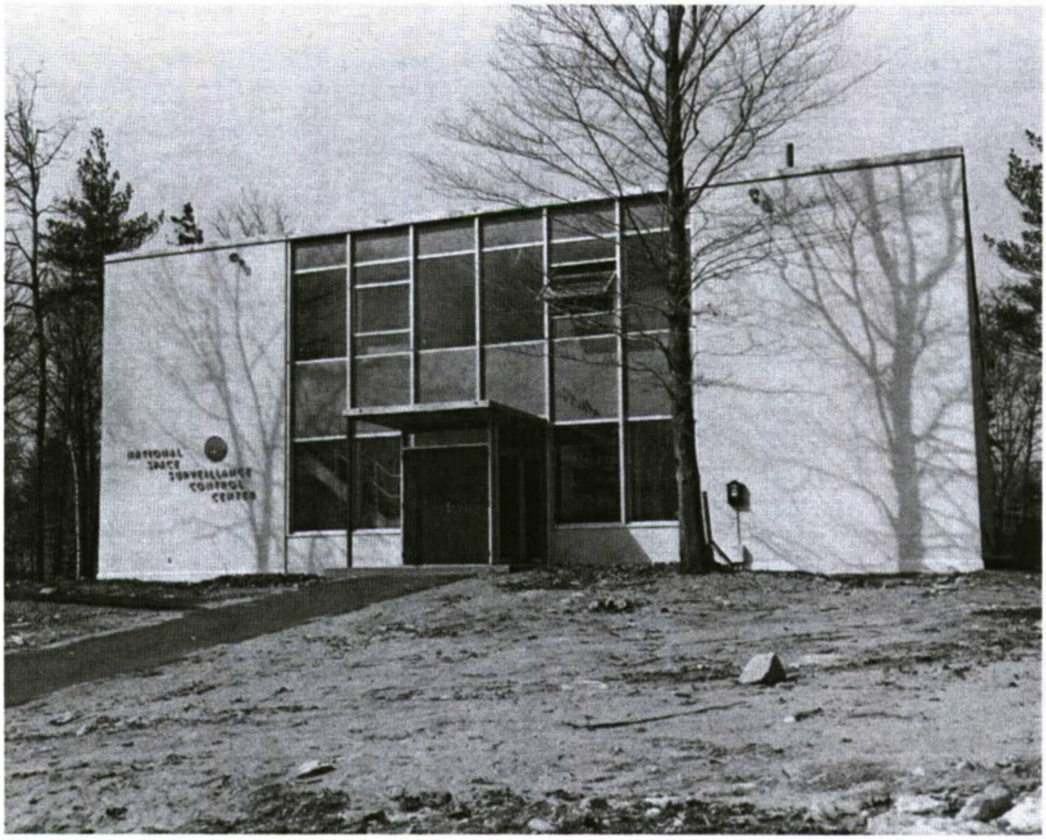

Plate 114: National Space Surveillance Control Center (Building 1435), Hanscom Air Force Base, 1958-1959. Undated photograph. Courtesy of the History Office, Electronic Systems Center, Hanscom Air Force Base.

final operational facilities at Ent Air Force Base in Colorado. While the Electronic Systems Center trained personnel for Ent, ADC built its Space Defense Center for SPADATS inside Cheyenne Mountain collocated with NORAD's Combat Operations Center. Internally, the Hanscom and Ent tracking control centers were similar, with men at computer consoles facing charts of information used to establish and maintain a master catalog of man-made items orbiting in space. Externally, the two spacetracking control centers were very different. The Hanscom facility was a training center that was detailed on all four facades by alternating horizontal bands of fixed glass and porcelain-enamel paneling. The Space Defense Center in Cheyenne Mountain was a steel building surrounded by rock, a fully hardened command post. As of July 1961, the National Space Surveillance Control Center at Hanscom converted to its long-term role to "improve the present system and plan for the future." The Hanscom unit kept a contingent of ADC personnel as backup for the Space Defense Center at Ent.[185]

The Air Force estimated that SPADATS costs would reach $185 million during 1964-1968. For Hanscom, SPADATS included the responsibility for developing the electro-optical surveillance test facility at Cloudcroft, New Mexico, to support the Air Force Satellite Program. The RADC had the task of developing a phased-array radar. Rome shifted site selection for the large phased-array radar from Trinidad—which had become increasingly unstable politically—to Florida. The comprehensive spacetrack sensor sites for SPADATS as of 1964 included the three BMEWS radars at Clear, Alaska; Thule, Greenland; and, Fylingdales Moor, England, as well as existing radars at Shemya, Alaska (to be replaced by Cobra Dane in the middle 1970s); Laredo, Texas; and, Moorestown, New Jersey. The

AN/FPS-85 at Eglin and the optical sensor at Cloudcroft (which could probe more than 20,000 nautical miles into space) would join the system as soon as they were operational (Plate 115). Patrick and Vandenberg Air Force Bases (the Atlantic and Pacific Missile Ranges) provided space traffic information too, as did the Air Force Satellite Control Facility at Sunnyvale, California (see Volume II, Chapter 9). NASA and the Navy also contributed data sources to the system.[186]

The AN/FPS-85 at Eglin

The Air Force simultaneously went forward with site planning for the AN/FPS-85 radar and decisions about its contractor. In December 1961, Headquarters Air Force favored the Avon Park Bombing Range associated with Homestead Air Force Base in southern Florida. Avon Park was already in use by SAC however, and was further earmarked for upcoming TAC missions. The Air Force, seeking a deactivated military installation in Florida reasonably distant from a population center, delineated its site search as "below 30 degrees N. latitude and east of Eglin AFB as far south as Trinidad and [the] Canal Zone." In late January 1962, the agency returned to the idea of Trinidad as the potential location for what would be the world's first large phased-array radar. Politics decided the Trinidad choice once and for all, and as of April the Air Force formally announced that Eglin would be the location of the radar. The very next month Trinidad achieved independence from its former colonial status. While the BMEWS prototype remained operational there, the radar was no longer considered a truly reliable military asset. During spring 1962, the RADC called for contractor proposals for the large phased-array radar. From remaining memoranda on the project, a team comprised of Sperry, Aeronutronic, Burroughs, Advanced Development Laboratories, and Bendix were among the front runners when the proposal went out for bid. Not surprisingly Bendix Radio Corporation of

Plate 115: Optical Sensor for SPADATS, Cloudcroft, New Mexico, 1962-1965. Undated photograph. Courtesy of the History Office, Electronic Systems Center, Hanscom Air Force Base.

Baltimore, the industry leader in phased-array technology research of the late 1950s, won the contract from the RADC in the spring of 1962.

Bendix had conducted internal company research during the late 1950s toward large phased-array radar, as well as prototype work for the RADC. The company built two test radars, in 1958 and again in about 1960-1961. In 1958, Bendix erected a 90-element, feasibility line-array radar atop its engineering building in Baltimore. Tests with the array proved that radar beams could be formed and steered electronically. Bendix then continued its exploration of phased-array radar through its Electronically Scanned Array Radar (ESAR), a radar of considerably larger scale built under a RADC contract at the Bendix test site near Baltimore in Towson, Maryland. The ESAR was in development as of 1958, first powered up in November 1960.[187] Bendix erected the ESAR to prove the feasibility of automatic computer control of its previously tested electronically steered radar beams. The Bendix radar in Towson was the immediate precursor to all American Air Force large phased-array radar, with the deliberate intent of using the technology for space tracking.

> Multiple-target tracking, accuracy, sidelobes, beam formation, construction techniques, and maintenance procedures were important features proven by this developmental system. It was a low-power "L" band system...The results of the ESAR project were so encouraging that the next logical step of building a high powered developmental system [the AN/FPS-85 at Eglin] was taken by the Air Force.[188]

The Bendix ESAR also employed a corporate rear feed system, rather than the front optical feed technology that was then the norm for large radars. This advancement was also pivotal for the large phased-array radar.

Bendix designed the large phased-array radar for Eglin on schedule, with drawings dating to late September 1962. The company worked with the architectural-engineering firm Whitman, Requardt & Associates, Inc., also of Baltimore. An early site plan showed the radar as it is configured today, but with the mapped intention of a "Future SPADAT Building" attached at the rear and identically reflected on axis. An electrical power station was attached behind the radar. While unbuilt, the full design for the Eglin radar is extremely noteworthy in its resemblance, in 1962, to the Perimeter Acquisition Vehicle Entry Phased-Array Warning System (PAVE PAWS) radars of 1975-1985. The AN/FPS-85 at Eglin faced due south, sited less than 10 miles from the Gulf of Mexico on what was then called the C-63 test site (today, C-6). The radar featured separate transmitting and receiving radar faces, configured side by side. The AN/FPS-85 was in its final testing in January 1965 when the radar suffered from a catastrophic fire. The RADC had originally considered the Eglin radar to be only an "R&D model." Reconstruction of the AN/FPS-85 began immediately, with a new letter contract between Bendix and the Air Force issued in May for "an operational, rather than R&D model." (The Air Force Directorate of Civil Engineering had labeled both the SPADATS radar at Eglin and the program's optical sensor at Cloudcroft, New Mexico, as "prototypes" in early 1962.) By late 1964, the SPADATS program included a "series of world-wide sites with a tracking center at Ent AFB"—with the Ent center, the optical sensor in New Mexico, and the AN/FPS-85 at Eglin approaching operational status simultaneously. The redesigned radar featured enhanced emergency power, deluge system, cafeteria, medical station, and emergency sleeping quarters. These features were partly upgradings in reaction to the Cuban missile crisis and a growing concern about the SLBM threat, as well as precautions against fire. The Air Force studied the causes of the fire into mid-June 1966 to fully investigate the flame-producing materials in the radar's design and construction, and to augment the overall system through "redundant equipments for improved availability."

Bendix reconstructed and improved the AN/FPS-85 by spring 1968, with a year of interface testing completed and final testing underway. During the summer of the same year, the AN/FPS-85 provided data to the Space Defense Center at NORAD. Air Force personnel ran the radar even before its official turnover to the agency, with the 20th Missile Warning Squadron activated at the facility as of January 1967. The Air Force took full ownership of the AN/FPS-85 on 20 September 1968—a full decade after beginning work on the ESAR at Towson for the RADC. The radar measured approximately 350 feet long, 155 / 95 feet tall (receiver / transmitter), and 155 feet deep (Plate 116). The transmitter array featured 5,184 dipole antennas as configured in 1968, with space for expansion. The receiver array featured 19,500 dipole antennas—4,600 of which were active, with the remainder terminated. The transmitter focused its energy into a "single beam which can be switched from one position to another within 20 microseconds, thus, allowing the radar to perform multiple tracking and surveillance functions much as though it had 200 tracker radars on the spot." The AN/FPS-85 could track 200 known satellites "and / or 40 unknown satellites in near real-time." Range for the radar was about 2,000 miles. Through the capabilities of the AN/FPS-85, the Aerospace Defense Command (ADC after 1967) reassessed the tactical situation 20 times a second and viewed "all except extremely high altitude satellites twice a day."

The Air Force realized that it needed a radar network to provide surveillance for possible Soviet SLBM launches immediately after the Cuban missile crisis. Within a few years, ADC further noted that the Soviet SS-N-4 and SS-N-5, as well as the Soviet submarine-launched cruise missile, the SS-N-3A, all posed serious threats. The Electronics Systems Division at Hanscom proposed an SLBM Detection and Warning System to meet Air Force needs. In the first half of 1966, the

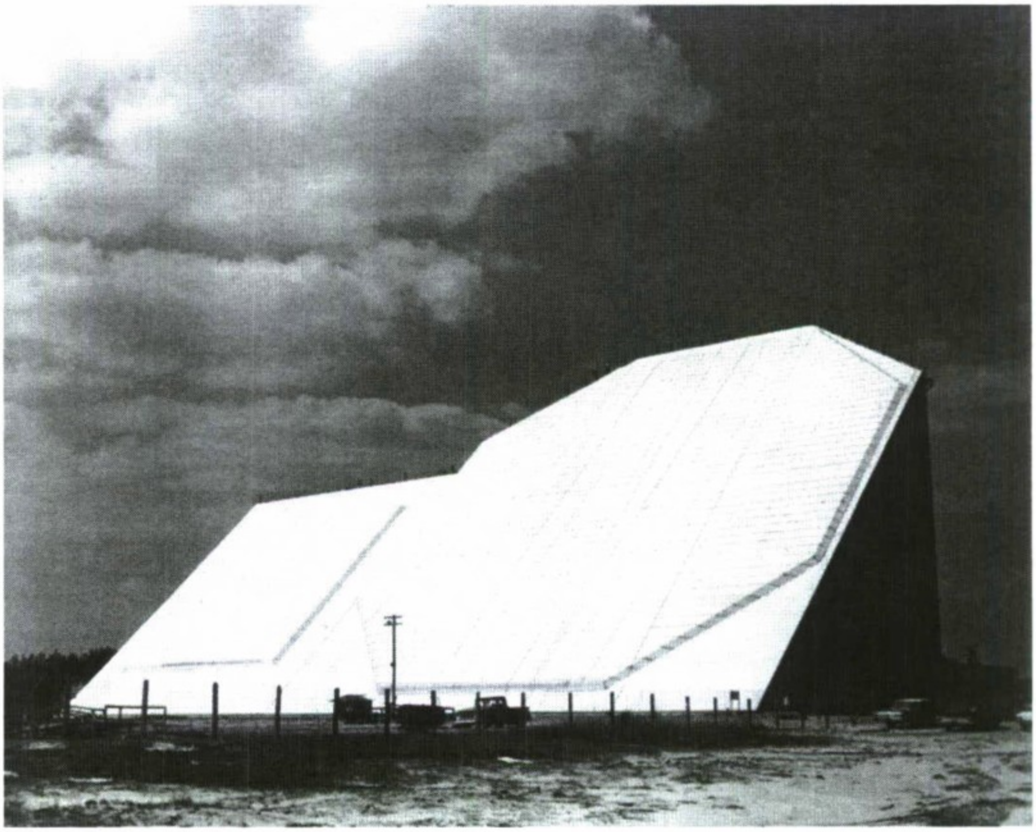

Plate 116: Bendix. AN/FPS-85 Radar (Site C-6), Eglin Air Force Base, ca.1966-1967. Courtesy of the History Office, Rome Research Site, AFRL.

Electronics Systems Division delineated a seven-radar system as an interim measure, using AN/FSS-7 radars to sustain "total coastal perimeter coverage" of the continental United States. The Electronics Systems Division also called out the AN/FPS-85 to support the SLBM protective warning web, and "for supplemental seaward coverage to the south. The AN/FPS-85 will perform its SLBM D&W [detection and warning] and SPACETRACK functions simultaneously by modification of its computer program." Both the United States Air Force and the Army began to reassess and redefine large phased-array radar with the deployment of the AN/FSS-7 system and the signing of the Antiballistic Missile (ABM) Treaty between the United States and the Soviet Union in 1972. By the treaty date, the Air Force sponsored both the AN/FPS-85 at Eglin and initial efforts toward the Cobra Dane large phased-array radar for Shemya, Alaska, at the tip of the Aleutians. Cobra Dane was an intelligence radar capable of verifying Soviet launches from its missile test ranges and from a known submarine launch area to the near west. The radar was a Raytheon project contracted in mid-1973 and operational in 1977, another joint effort of the Electronic Systems Division at Hanscom and the RADC. Cobra Dane brought Raytheon into prominence for large phased-array technology. Also during 1972-1975, the Army completed construction of the Safeguard ABM Missile Site Radar (battle management) and Perimeter Acquisition Radar (tracking) in North Dakota—deactivating the MSR in 1976 and transferring the PAR to the Air Force for a high-altitude polar-orbit tracking mission complementary to Eglin's responsibility for high-altitude equatorial tracking.

In 1973, the AN/FPS-85 was the only existing operational large phased-array radar handling American air defense needs and providing potential missile-track intelligence. That year the Air Force formally announced that Eglin's radar would supplement the AN/FSS-7 network to track SLBM launches from the Caribbean—a mission proposed for the radar as early as 1963. Simultaneously, the Air Force assigned the AN/FPS-85 a backup mission for NORAD, as the Alternate Space Defense Center. In this role the radar was to take complete, or partial, command from NORAD in Cheyenne Mountain should that be needed, and replaced the National Space Surveillance Control Center at Hanscom in this mission. NORAD facilities in Cheyenne Mountain were activated in 1965. As of 1973, the AN/FPS-85 devoted one-third of its time to space surveillance, with two-thirds of its time assigned to acquire and track specific targets as directed by NORAD. The new SLBM mission was operational in mid-1974, with the radar reallocated to 30 percent space surveillance, 50 percent space tracking, and 20 percent SLBM early warning. During an SLBM attack, the Air Force tasked the AN/FPS-85 to drop its space tracking workload to determine projected missile impact points. In 1973, the AN/FPS-85 observed 95 percent of the approximately 2,700 objects and debris then in space, one or more times daily. (In 1964, 1,200 objects were in orbit, while today more than 22,000 man-launched objects are under space surveillance.) The radar observed NORAD-assigned targets 15-20 times daily, with more than 10,000 observations in a 24-hour period.

The Air Force upgraded its sophisticated radars during the 1976-1991 years. The primary mission of the oldest of American large phased-array radars, the AN/FPS-85 at Eglin and the PAR in North Dakota (renamed the Perimeter Acquisition Radar Attack Characterization System [PARCS]), was and remains space tracking. (By the end of 1977, PARCS received a satellite tracking mission and was subsumed under SAC, and subsequently under Space Command / AFSPC.) Eglin's radar tracked about 85 percent of the space object catalog, while PARCS tracked about five percent. Between 1971 and 1984, the AN/FPS-85 continued to serve as the Alternate Space Surveillance Center for NORAD. The radar also sustained a partial SLBM early warning mission until the PAVE PAWS large phased-array radar achieved operational status at Robins Air Force in Georgia during 1986 (see below). The Air Force upgraded the AN/FPS-85 in the years immediately following the end of the Cold War. The radar reacquired an SLBM tracking role in 1995, when the Air Force took the Robins PAVE PAWS off line.

PAVE PAWS

The Air Force PAVE PAWS program was to have four large phased-array radars, located in the northeast, northwest, southeast, and southwest. The Electronic Systems Division at Hanscom, working with the PAVE PAWS contractor Raytheon, planned PAVE PAWS to establish a radar surveillance fence around the North American land mass. The Air Force Program Directive for an SLBM phased-array radar was established in 1973. Preliminary work occurred during 1974-1976, with Raytheon constructing a PAVE PAWS test array of antenna dipole elements atop the roof of its Equipment Division building in suburban Boston. The Air Force established the sites for the PAVE PAWS to catch the trajectories of Soviet SLBMs launched from known submarine patrol. At the outset of the planning, the Air Force referred to the AN/FPS-85 and Cobra Dane as the most important direct models for PAVE PAWS. The Electronic Systems Division selected final locations for the radars in 1975 after considering three possible choices in the east and west. In Massachusetts were Otis Air Force Base, North Truro Air Force Station (an ADDC and a BUIC site), and Westover Air Force Base, while in California and Oregon were Beale Air Force Base, Mill Valley Air Force Station near San Francisco (an AC&W radar site and one of the seven AN/FSS-7 SLBM radar stations) and Mount Hebo Air Force Station, Oregon (an ADDC, as well as an AN/FSS-7 station).[189] As initiated, the program supported two radars: at Otis (with the PAVE PAWS there later becoming Cape Cod Air Force Station, managed as a subinstallation of Hanscom Air Force Base) and at Beale, north of Sacramento. Very high costs, as well as rapidly advancing radar and computer technologies, partially accounted for the initial downscaling of the major new air defense system. Raytheon received the contracts for the Cape Cod and Beale PAVE PAWS in 1976, following the company's work in the research, development, and test for the system. The radars were under construction at both sites between 1977 and 1980, with Raytheon system performance testing beginning in 1978.

Raytheon designed and built the Cape Cod and Beale PAVE PAWS as nearly identical. The PAVE PAWS incorporated key elements present at Cobra Dane, and marked a departure from the physical configuration of the AN/FPS-85 at Eglin. The overall form was a truncated pyramid. The structure that housed the radar was steel-frame with aluminum-panel cladding. For the first time, large phased-array radar featured two radar faces instead of one (although Bendix had planned for such a configuration at the AN/FPS-85). All PAVE PAWS featured a 20-degree set-back, a design change more appropriate to SLBM watch than was the 45-degree angle of the AN/FPS-85. With the PAVE PAWS, large phased-array radar hardware continued to become simplified. Transmitter / receiver (T/R) modules replaced the Bendix tetrodes and Raytheon traveling wave tubes of the AN/FPS-85 and Cobra Dane. The dual radar face of PAVE PAWS radars expanded the coverage area from 120 degrees to 240 degrees in azimuth. (Phased-array radar deteriorates in its electronic scanning capabilities at 60 degrees from boresight, thus creating the 120-degree side-to-side characteristic of a radar face.) The Air Force sited both the Cape Cod and Beale PAVE PAWS (AN/FPS-115 radars as built, now upgraded as AN/FPS-123s) on hilltops, which was important to assure optimum working of the equipment. The Cape Cod radar, sequentially overseen by ADC, SAC, and Space Command / AFSPC, became operational in April 1980, with Beale following within several months. Both PAVE PAWS tracked American ICBM, SLBM, and satellite launches. The radars also served in a space tracking capacity, as well as provided potential early warning of Soviet attack.

During 1981, Electronic Systems Division initiated planning for a PAVE PAWS at Robins and at Eldorado Air Force Station (near Goodfellow Air Force Base) in Texas. The Air Force performed surveys between June 1981 and late 1982 for locations under consideration. In the Southeast, Electronic Systems Division looked at both Moody and Robins in Georgia, while the division evaluated three ranch sites in West Texas. Raytheon won the PAVE PAWS contracts in 1983 and 1984, respectively. AFSPC activated each radar, with Robins operational in 1986 and Eldorado in 1987 (Plate 117). The second pair of PAVE PAWS (AN/FPS-123 radars) were significantly more

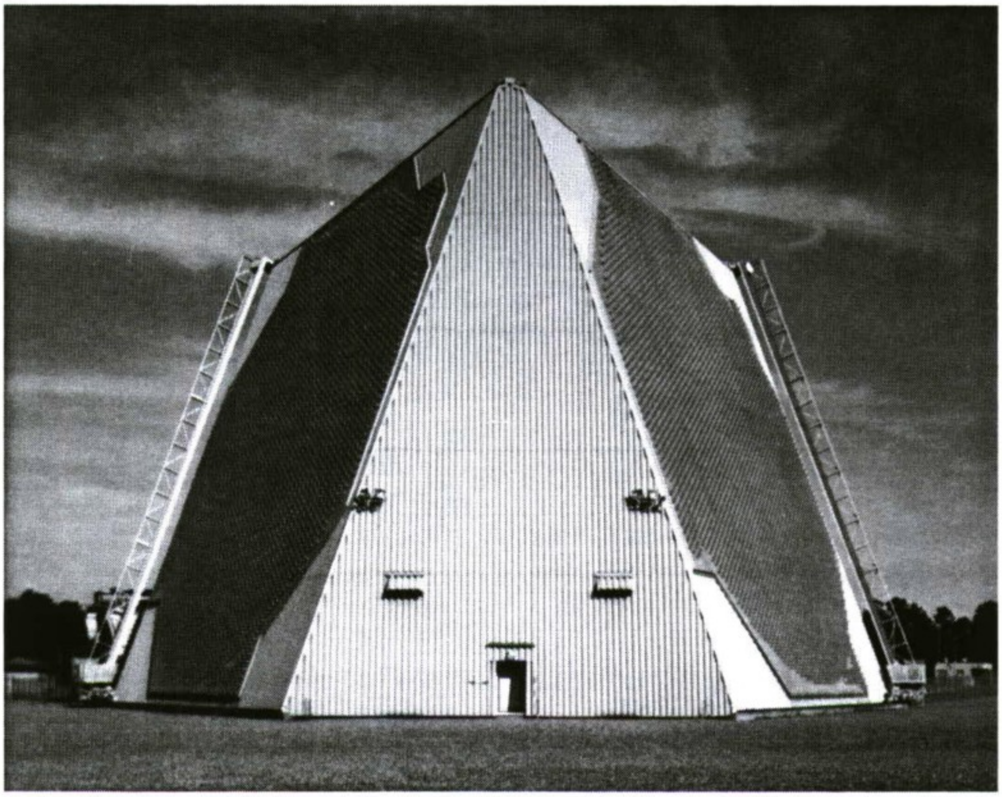

Plate 117: Raytheon. PAVE PAWS (AN/FPS-123), Robins Air Force Base, 1983-1986. HAER photograph of 9 September 1998. Richard T. Bryant for Argonne National Laboratory. Courtesy of Robins Air Force Base.

powerful than those originally built at Cape Cod and Beale. During the early 1980s, several stimuli had led to the expansion of the PAVE PAWS and to that of American large phased-array radar in general. Soviet submarine activity increased in the Caribbean and Pacific, and the Chinese obtained SLBM capability. More to the point, the American large phased-array radar system, in its piecemeal buildout, was directly reflective in numbers and technology to that of the Soviet Union. The first Soviet large radar network, the Hen House, had a follow-on long-range surveillance radar system, Hen Roost, under initial construction simultaneously with the Cape Cod and Beale PAVE PAWS. By the date of Air Force contracting for the Robins and Eldorado PAVE PAWS, the Soviet Union had completed five Hen Roost large phased-array radars. At that time, the United States Air Force also managed five large phased-array radars: at Eglin, in North Dakota, at Shemya, at Cape Cod, and at Beale. The sixth Soviet Hen Roost radar of mid-1983 proved highly controversial in terms of the ABM Treaty, and President Reagan's Star Wars speech of March that year only aggravated the situation. Both sides embarked on a military buildup, including large phased-array radar. In addition to the third and fourth PAVE PAWS, the Air Force began replacing the BMEWS radars with large phased-array equipment, with the Thule radar under contract as of July 1983. While not given the acronym PAVE PAWS, the large phased-array radars built at the BMEWS sites were all of nearly identical type.

After the conclusion of the Cold War, many issues have continued to surface with regards to the American and Soviet large phased-array radars. Both nations eventually built a system of 10 radars. (The tenth American radar was that at Clear, Alaska. This AN/FPS-123 replaced the earlier BMEWS radars on site, and was operational in early autumn 2000.) From the start, the PAVE PAWS at Robins experienced serious problems in interference between the microwaves of the radar and the

sophisticated electronics of aircraft using the base runway. Both the Robins and Eldorado PAVE PAWS were also somewhat questionable with regards to stipulations within the ABM Treaty. In 1995, the Air Force took both radars off line, with that at Eldorado used to provide almost all of the parts required for the large phased-array radar built at Clear (leaving a virtual shell in Texas). The Robins PAVE PAWS went into a sustained storage condition simultaneously. In 2003, the large phased-array radar at Eglin is under consideration for additional upgrading in the missile defense shield sought by President Bush, as are other radars within the group of large-phased array radars originally built during the 1960s-1990s. The ABM controversy no longer applies to the radars, with the United States removing itself from the treaty in June 2002.

The Presence of NASA

Installations under ARDC / AFSC and Air Materiel Command / AFLC also sustained a strong connection to NASA, from that agency's beginnings as the National Advisory Committee for Aeronautics (NACA) forward. The strongest relationship was at Edwards Air Force Base, in place there as early as 1946. Missions at Wright-Patterson also maintained multiple ties to NACA / NASA, with overlapping Cold War agendas. In addition, NASA's space missions were intrinsically linked to near-earth and high-altitude testing at the Cambridge Research Center (Laboratories) at Hanscom. Also, launch sites on Eglin's Santa Rosa Island of the late 1950s through the 1960s accommodated selected NASA missions, while the BMEWS radar prototype test site in Trinidad for the RADC (coupled with the Floyd Test Site in New York) contributed to a major NASA mission in 1960. The Air Force Ballistic Missile Center (AFBMD) (later, multiple follow-on organizations at Los Angeles Air Force Station / Base) worked on launch vehicles that supported manned NASA capsules, as well as satellites. Its subinstallation, the Air Force Satellite Control Facility (Onizuka Air Force Station) in Sunnyvale, California, is collocated with NASA's Ames Aeronautical Laboratory. In yet another arena, the Air Force Aerospace Medical Center at Brooks Air Force Base in San Antonio, as of 1959-1960, was a key contributor to space medicine breakthroughs for NASA from that date through the end of the Cold War. In the field of aviation medicine, Wright-Patterson's aeromedical laboratories also experimented in high-altitude flight and space environments from immediately after World War II and, along with the Aerospace Medical Center, supported NASA as the Cold War evolved.

The complexity of the NACA / NASA mission at Edwards began immediately after World War II with the activation of the NACA Muroc Flight Test Unit at Muroc Army Airfield in 1946 (today's South Base at Edwards).[190] The Muroc Flight Test Unit was a satellite installation of NACA's Langley Aeronautics Laboratory in Virginia, and followed the 1939-1940 West Coast establishment of the NACA Ames Aeronautical Laboratory at Moffett Field in northern California. As NACA expanded during the war, a third research site went in place for aircraft engine research in Cleveland (named the Lewis Flight Propulsion Laboratory in 1948). Guided missiles testing also began at Eglin and at another NACA site of 1945, Wallops Island, Virginia, stimulated by research derived from the German V-1 and American JB-2. Edwards hosted the Army Air Forces Materiel Center Flight Test Base (at today's North Base) as of 1942, established to test the highly classified Bell Aircraft XP-59A. The XP-59A was the United States' first jet aircraft, and its basic R&D goals toward future flight strongly paralleled goals of NACA. At this juncture, testing toward jet aircraft was splintered and competitive between the Army Air Forces and the military-civilian NACA. Resolution of many issues centered on the relative roles of basic and applied research became paramount after the war (see Volume I, Part III). By early 1946, NACA was to handle fundamental research, with industry contracted to develop the technologies. The military service arms were to test and evaluate the products. Lines blurred between NACA and the R&D efforts of Air Materiel Command, with continued ties throughout the Cold War. NACA located its Flight Test Unit at Muroc Army Airfield in part due to the existence of the Army Air Forces Materiel Center Flight Test Base at the same installation.

In 1949, the Muroc NACA station underwent a slight name change to the High-Speed Flight Research Station, but remained at its earlier location (South Base) subsumed under the Aeronautics Laboratory at Langley. That year, Muroc Air Force Base became Edwards, in honor of a pilot testing the Northrop Flying Wing. In 1948, NACA received title to an independent "NACA hangar" on South Base, made improvements to the facility, and added offices and dormitories. A primary mission of NACA at Edwards was the testing of aircraft at the frontiers of aeronautical R&D. Contracted pilots flew prototype aircraft, with initial work toward supersonic speeds and swept-wing design. The aircraft industry, with major offices and plants in Southern California, often delivered one plane to NACA and one to the Air Force for concurrent testing at Edwards and at the Air Force industrial plant facilities at Palmdale Airfield nearby (AFP 42). Aircraft industry contractors also had hangars and office space at Edwards in support of the testing process. As of 1950, NACA granted its High Speed Research Station at Edwards an independent operating budget, in the first true step toward an autonomy from Langley. The next year, Congress funded new laboratory facilities for NACA at Edwards to solidify the change. NACA's rise at Edwards was nearly coincident with the official prominence of Air Force aeronautics R&D through the formalization of ARDC. On 1 July 1954, NACA's facilities at Edwards became independent as a major research center. NACA renamed its cluster the High Speed Flight Station and moved to a new site on the installation (under construction as of 1953). NACA leased land from the Air Force for its facilities at Edwards. The agency constructed its own hangars, research laboratories, shops, administrative space, and other related quarters. Both NACA and Air Force test pilots trained at the Air Force Test Pilot School which had opened at the beginning of the decade and was also located on the base. During the remainder of the 1950s, NACA and the Air Force concentrated on testing the X-series of aircraft at Edwards. NACA's X-series testing program contributed substantially to the Air Force's century-series fighter jets of the late 1950s and 1960s.

In 1958, the new space agency NASA absorbed NACA, with the Edwards test site renamed the next year as the NASA Flight Research Center. The establishment of NASA, derived from the Space Act signed by President Eisenhower in July 1958, underlined the space race unfolding between the United States and the Soviet Union. The shift also elevated the agency's presence at Edwards. NASA had merged parts of multiple organizations, including NACA, the Army Ballistic Missile Agency (where Wernher von Braun's large contingent of German scientists continued to reside as of the late 1950s as the genesis of the Marshall Space Flight Center in Alabama), the Naval Research Laboratory (personnel from which provided the nucleus of the Goddard Space Flight Center in Maryland), and the Air Force Ballistic Missile Program. While NACA had conducted the majority of its R&D with in-house staff, NASA turned to contracting through industry and universities. NASA began to develop its own area at Edwards as the Rocket Engine Test Laboratory, with its first test stands operational in 1961. The facilities accommodated test firing for the engines of NASA's satellite launch vehicles, as well as those of the launch vehicles for spacecraft (for the Mercury, Gemini, and Apollo programs).

NASA shifted to space research at Edwards following testing for the supersonic X-15. Astronauts trained through the test pilot school on base, which was renamed the Air Force Aerospace Research Pilot School as of mid-October 1961. As a result of NASA and Air Force testing at Edwards, the X-15 reached Mach 8 and flew above 80 kilometers (49.71 miles) by 1963. Both agencies interpreted the achieved altitude as a boundary of possible spaceflight. As of 1965, fully 80 percent of NASA's R&D was for space study. Also in that year, the Air Force Flight Test Center (under AFSC) and NASA began concerted work toward a space shuttle. Both the Apollo program that led to a successful lunar landing, and the space shuttle program, were vital NASA projects involving its Edwards facilities. The dry Rogers Lake Bed served as the primary shuttle landing site for 32 out of 41 missions that occurred before the end of the Cold War (Plate 118). After 1991, NASA's main shuttle landing location shifted to the Kennedy Space Center (formerly, Cape Canaveral) in Florida.

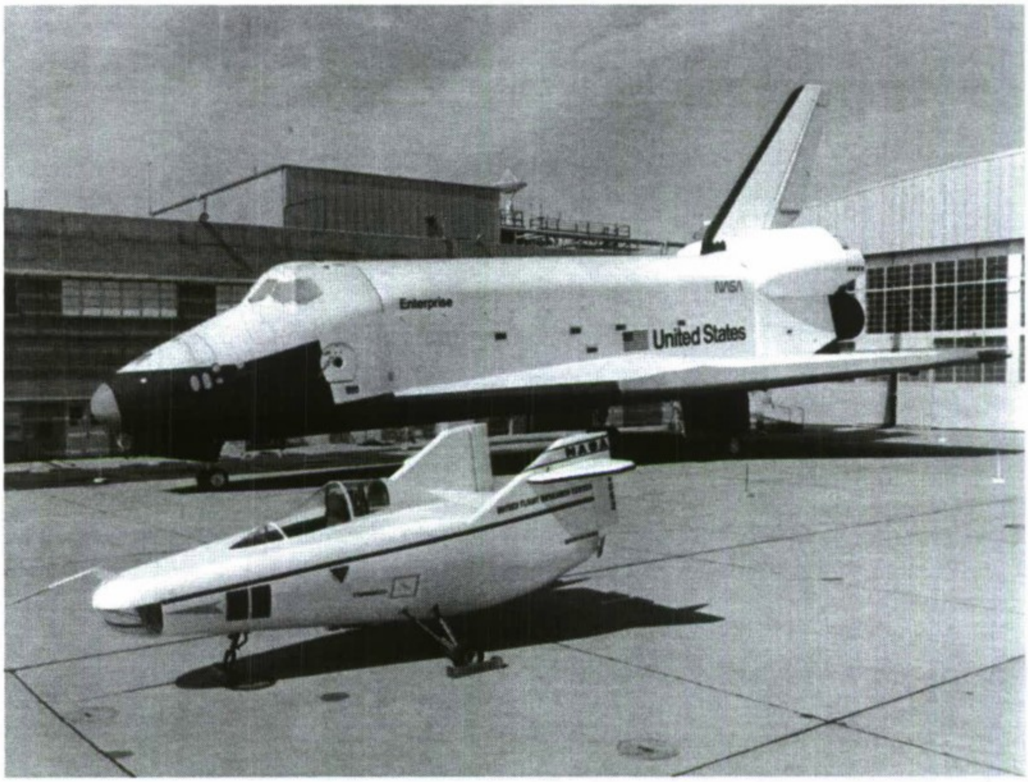

Plate 118: The M2-F1 (first flown in 1963) and the Space Shuttle Enterprise (first flown in 1977). Hugh L. Dryden Flight Research Center, Edwards Air Force Base, ca.1977. Courtesy of the History Office, Edwards Air Force Base.

In 1976 and 1981, NASA's test site at Edwards took on its two final names of the Cold War period: the Hugh L. Dryden Flight Research Center and, after administrative consolidation with the Ames Research Center in Sunnyvale, the Ames-Dryden Flight Research Center.

Air Force geophysical research at Hanscom also aligned very strongly with the space missions of NASA.[191] The Geophysics Research Directorate within the Cambridge Research Laboratories had originally drawn upon personnel of the Radiation Laboratory at MIT (disbanded after World War II) and from the Atmospheric Laboratory of the Watson Laboratories in New Jersey. The Directorate continued to make major contributions in geophysical research within the Cambridge Research Center / Laboratories until 1976, paired with the Electronics Research Directorate (later, Electronics Systems Center and Electronic Systems Division). In that year, the geophysics branch became the Air Force Geophysics Laboratory. In 1982, AFSC began to consolidate its key space research laboratories through the Air Force Space Technology Center at Kirtland, with the Space Technology Center tiered to Space Division at Los Angeles Air Force Station. Geophysics research continued within a distinct laboratory at Hanscom until the end of the Cold War, when the organization became part of an AFSC super-laboratory, the Phillips Laboratory. In December 1990, the Phillips Laboratory combined former laboratories at Hanscom, Rome, Edwards, and Kirtland—which AFSC had previously grouped together through the Air Force Space Technology Center. As space and atmospheric research accelerated and became more complex, the Geophysics Research Directorate of the Cambridge Research Center / Laboratories worked in tandem with new federal civilian agencies as they appeared: NASA in 1958, the National Center for Atmospheric Research (NCAR) in 1960, and the National Oceanic and Atmospheric Administration (NOAA) in 1969. Post-Sputnik, these rising agencies took over some areas of geophysics research from Cambridge, just as NACA / NASA

had pulled away selected aeronautical research from Wright-Patterson. Nonetheless, Air Force geophysics research continued to be intertwined with multiple NASA missions.

Evidence of the geophysics relationship between the Cambridge Research Laboratories and NASA include efforts from the late 1950s until the end of the Cold War. The Geophysics Research Directorate sponsored Project Satellite Cloud Photo to study possible uses for satellite-televised imagery in meteorology. The Directorate attached a camera to a ballistic missile launched from Patrick to simulate satellite imagery (which had not yet occurred). As in other high-altitude tests, where cameras had been attached to Aerobee sounding rockets, the capsule containing the camera separated at the desired altitude, photographed imagery as programmed, and parachuted to earth for retrieval over the Atlantic Missile Test Range. NASA followed in April 1960 with launch of the first weather satellite, the Tiros I. Tiros I also photographed from space. The Geophysics Research Directorate at Hanscom, as well as the Air Weather Service, analyzed cloud cover for the first time as viewed from an actual satellite. The cloud study research, invaluable for advancements in meteorology, was seamlessly linked between ARDC and NASA: from the efforts of the Geophysics Research Directorate to NASA, and back to the scientists at the Directorate. Also during the early years of NASA, the Directorate (along with its electronics counterpart within the Cambridge Research Laboratories) supported SPADATS. Hanscom personnel contributed to the success of satellite tracking from both the Air Force point of view and that of NASA. The Geophysics Research Directorate participated in studies of satellite survivability in space, astronaut safety, and protection of ground communications links.

In another example of cross-agency cooperation, Geophysics scientists at the Cambridge Research Laboratories worked with their counterparts at NASA and NOAA to monitor solar emissions. This data was needed for space weather forecasting. The Air Force, NASA, and NOAA have measured optical, radio-burst, ultraviolet, and x-ray solar emissions since the early 1970s, with work at the Cambridge Research Laboratories as early as 1951. The Cambridge Research Laboratories created the prototype instrumentation for ground-based observations stations able to monitor optical and radio emissions. AFSPC has subsequently linked selected of these stations together as the Solar Electro-Optical Network (SEON). Responsible for the SEON mission, the sister Air Force agency turns to the Geophysics Research Directorate at Hanscom for solving operational problems and for upgrading technical support. The Directorate has also developed space environment models, both indirectly through the funding of university research (such as research at Rice University leading to the Magnetospheric Specification and Forecast Model) and directly through the work of its own physicists (such as the Parameterized Realtime Ionospheric Specification and Forecast Model). The Air Force Geophysics Laboratory flew Space Radiation Effects (SPACERAD) experiments on the joint Air Force / NASA Crees satellite in 1990-1991. Data collected from these experiments revised the standard NASA models of space radiation belts that are required by satellite designers.

The Cambridge Research Laboratories made continuous contributions in high-altitude and space balloon science. In the 1960s, NCAR established a balloon launch facility at Palestine, Texas. (Earlier ARDC facilities had been at Holloman Air Force Base and other independent locations—see Volume I, Part III.) Again, a key role of the Geophysics Research Directorate was to provide expertise to NCAR, as well as to offer selected personnel for the Palestine facility. NCAR subsequently transferred the balloon launch facility in Texas to NASA. During the 1970s, the Directorate significantly improved the size of the polyethylene balloons and their payload weight capacity. The Directorate also set new records for the altitudes achieved by these unmanned, free-flight balloons and made lasting contributions in the areas of launch techniques, command and control, and instrumentation (carried on the balloon gondolas). The Directorate assisted NASA in its development of the reentry systems for lunar and planetary probes through balloons developed as tethered aerostats. Cambridge balloons were a basic component of NASA drop tests as of 1965.

NASA studied its prototypical lunar reentry system for the Surveyor Lunar Lander using a tethered Cambridge balloon for a drop test in that year. The space agency followed with further reentry drop tests from free-flying balloons for the Voyager and Viking probes of Mars in 1966 and 1972, the Pioneer probe of Venus in 1977, and the Galileo probe of Jupiter in 1982. (Drop tests with attached parachutes were standard in earlier decades as well. These tests typically used dry lake beds and alkali flats at American military installations such as Holloman and Edwards.) Personnel in ground stations directed the balloon-carried probes to the appropriate high-altitude locations. In descent, they managed the openings of a series of parachutes attached to the probes and thus simulated theoretical probe descent (reentry).

Aerospace launches from facilities on Santa Rosa Island at Eglin of the late 1950s through the 1960s were also linked to NASA high-altitude and space research.[192] As of 1955, construction was underway for high-altitude sounding rocket launchers at Site A-11 on Santa Rosa Island. By the end of the decade, the site included a segregated Sparrowbee / Aerobee launcher and four clustered launchers (three of 170-degree type and one an advanced multistage launcher). Of the four launchers, one of the former was originally for Cree, while the multistage launcher was for Exos. The remaining two general-purpose launchers first accommodated Nike-Cajun rockets that carried high-altitude test packages. During early 1960, Eglin personnel fired three Aerobee 300 sounding rockets in support of a control communications feasibility test for the Wright Air Development Center (WADC). Detachment 2 of the Air Force Research Division at Hanscom, directly tied to the Geophysical Research Directorate of the Cambridge Research Laboratories, fired Aerobee 150 test vehicles from Santa Rosa Island in April (Plate 119). The first Aerobee 150 reached a maximum altitude of 147 miles in 4.35 minutes, with a total flight time of just over eight minutes. A second Aerobee 150

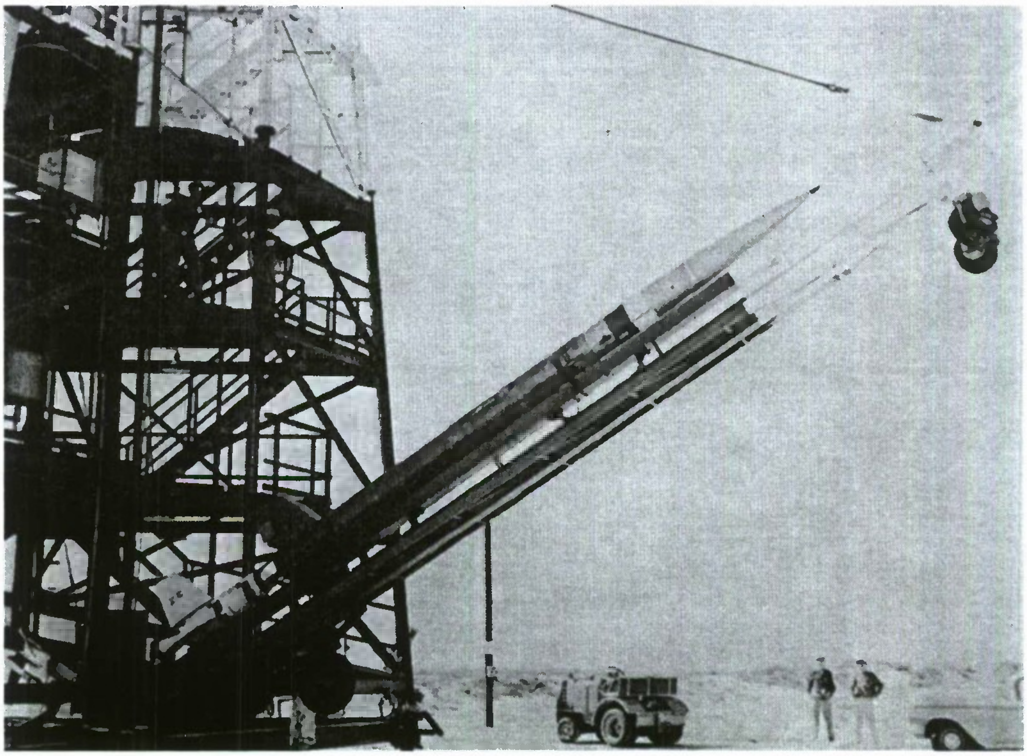

Plate 119: Aerobee Launch Site, Santa Rosa Island, Eglin Air Force Base, 1961. Test firing of an Aerobee 150. In *History of the Air Proving Ground Center 1 July – 31 December 1961*, volume 4.

attained an altitude of 154 miles, then descended over the Eglin Gulf Test Range about 165 miles off the coast of the Gulf of Mexico. In late March, personnel had launched the prototype model of the Astrobee 500, a two-stage high-altitude probe. The Geophysical Research Directorate had begun testing the Exos from the multistage launcher in mid-February. The Exos was a three-stage high-altitude, solid-propellant rocket used by the Directorate to explore the earth's upper atmosphere. (The Air Force and NASA had jointly launched the first Exos sounding rocket from Wallops Island, the NASA launch site off the coast of Virginia, in September 1958.) Detachment 2 of the Air Force Research Division had also fired a Nike-Cajun probe in February, with the test package separating from the guided missile for the planned experiment (Plate 120).

Between 1961 and 1965, the Air Force expanded high-altitude probe operations on Santa Rosa Island at Site A-11, alternately referencing the location as the Vertical Probe Launch Site. During the first six months of 1961, launches included a Nike-Cajun firing on 23 February in support of a Cambridge Research Laboratories project studying atmospheric density "by the falling sphere technique." On 1 March, the Directorate of Aerospace for the Air Proving Ground Center at Eglin launched a Nike-Asp sounding rocket, again in support of Cambridge Research Laboratories investigations into "the very low frequency propagation and the transmission characteristics of the ionosphere at low radio frequencies." The Directorate of Aerospace launched two more Nike-Cajun probes in March for Cambridge experiments. During the second half of 1961, activities at Site A-11 included another Exos launch in August. The three-stage Exos combined a first-stage Honest John rocket with a second-stage Nike and a third-stage Yardbird. The University of Michigan, NASA, and the Cambridge Research Laboratories had developed the Exos as a joint effort. As the month concluded, personnel launched a second Nike-Asp at Site A-11 to continue research on very low frequencies. Intense use of the vertical probe facilities also included launches of a United States Navy vehicle, the T-Bird, Arcas-Robin, Cree, Terrier-Viper, Nike-Cajun, Aerobee 150, and Astrobee 200. One of the Nike-Cajun launches carried a micrometeorite counting payload, again for the Cambridge Research Laboratories at Hanscom.

Eglin's Vertical Probe Launch Site underwent physical change in the early 1960s for the high-altitude experiments conducted for the Cambridge Research Laboratories and NASA. The Aerobee area of the late 1950s served as the liquid-propellant vehicle complex and featured a 162-foot launch tower with immediate auxiliary facilities. The adjacent solid-propellant vehicle complex included three boom-type launchers for the Nike-Cajun, Nike-Asp, Exos, Astrobee, and similar rockets. The Jason boom-type launcher could be elevated to an angle of 90 degrees and was equipped with a 28-foot rail. NASA used Jason as a high-altitude probe for testing during 1958-1962. The Cree launcher was a modified Sergeant boom-type structure with a 40-foot rail and a launch elevation angle of 87 degrees. Personnel were also altering a Sergeant mobile launcher at the site to launch Nike-Cajun, Nike-Javelin, and other probes by late in the year. The Arcas-Robin launcher was a portable, stovepipe-type structure designed specifically to launch the seven-foot Arcas-Robin test vehicle (Plate 121). The Arcas-Robin gathered meteorological data at high altitudes. At Site A-11, Nike-Ajax launches continued into the early 1970s (Plate 122). Other high-altitude tests at the A-11 complex included ones for Trailblazer. As of mid-1967, additional launch areas on Santa Rosa Island for high-altitude probes included those at Site A-15A, adjacent to the Bomarc launch area, and vertical probe support at Site A-10.

The Air Force and NASA often derived these kinds of launch vehicles, otherwise known as sounding rockets, from surplus military rockets retired from service. As suborbital rockets, these launch vehicles achieved low-cost access to space, where the required observations or testing was of limited duration. NACA / NASA additionally used sounding rockets to study the near-earth environment, as well as to test spacecraft components and reentry vehicles. The Nike-Cajun was just such a vehicle, and had reached an altitude of about 87 miles. NACA had launched the first Cajun research rocket in

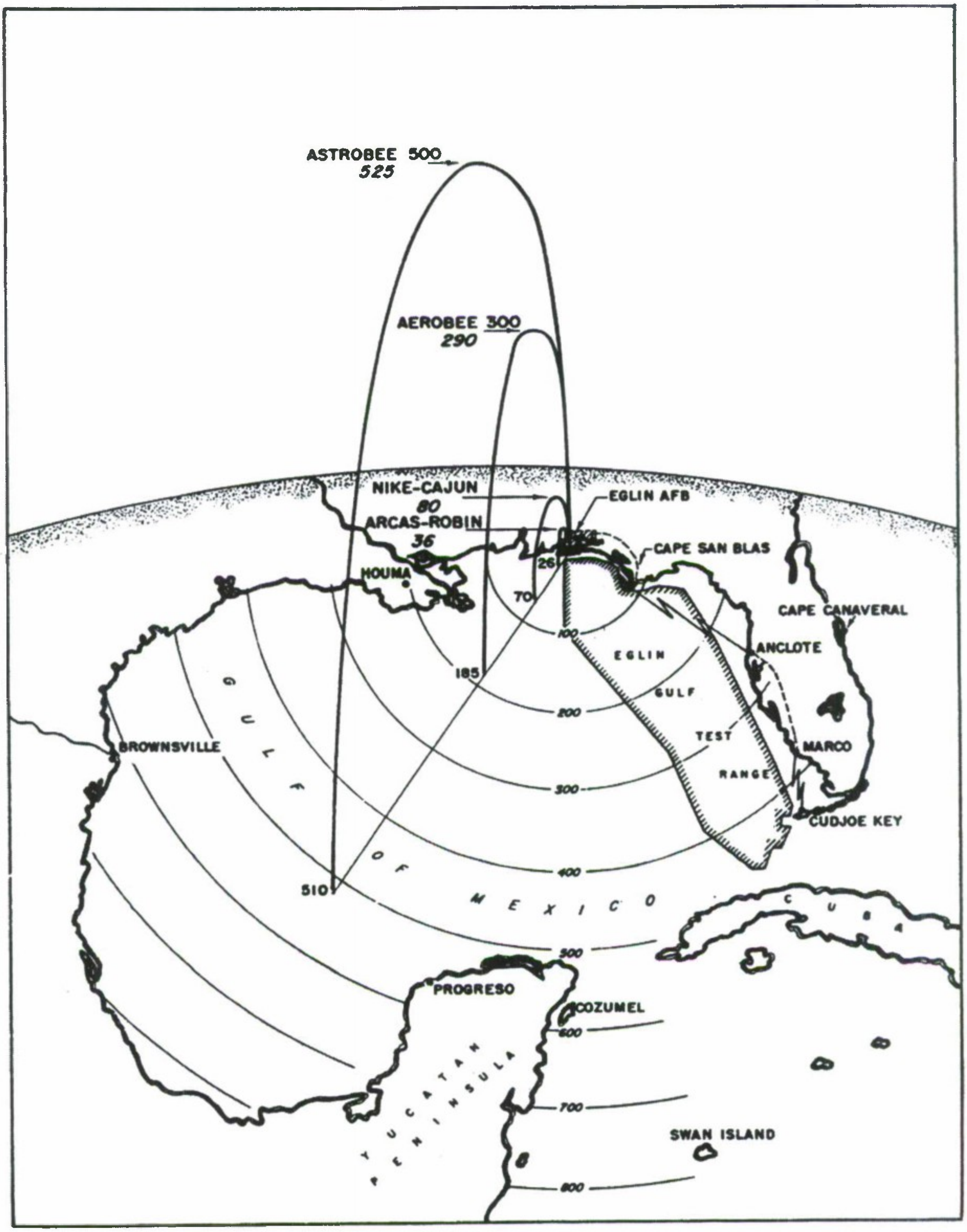

Plate 120: Typical Launch Trajectories over the Eglin Gulf Test Range from Santa Rosa Island, Eglin Air Force Base, 1961. In *History of the Air Proving Ground Center 1 July – 31 December 1961*, volume 4.

Plate 121: Arcas-Robin Launcher with Arcas-Robin Test Vehicle, Santa Rosa Island, Eglin Air Force Base, 1961. In *History of the Air Proving Ground Center 1 July – 31 December 1961*, volume 4.

mid-1956. The agency launched a variety of Nike-derived high-altitude probes, including the Nike-Deacon and Nike-Asp. The Nike-Asp achieved the highest altitude ever recorded by a ship-launched probe—over 155 miles—during studies of a solar eclipse. NASA had launched the first Trailblazer rocket from Wallops Island in April 1961. The Trailblazer was a multistage sounding rocket that featured seven stages by the close of the year. In another Wallops Island test in December 1961, Trailblazer's first three stages took an artificial meteorite to an altitude of 174 miles, while its final four stages redirected the rocket's payload back to earth. The Trailblazer payload entered the earth's atmosphere at 14,000 miles per hour in a high-altitude reentry study. The Arcas-Robin was a weather sounding rocket, with initial tests in May 1961. NASA fired 24 Arcas-Robins from the Eglin A-11 site that month. Launching the 500-pound Cree vehicle at Site A-11 had begun in early November 1961, for a test of a "ballute" reentry system. A Nike rocket boosted the Cree to 28 miles and reached a speed of 1,900 miles per hour. The ballute system, for balloon braking, slowed the Cree for successful reentry into the earth's atmosphere.

By mid-July 1964, the launch sites on Santa Rosa Island had hosted 500 high-altitude probe firings, a figure that climbed to 700 by early March 1966. In June that same year, Eglin's vertical sounding rockets supported the International Quiet Sun Year test series, with 17 launches. After this event, Air Force and NASA high-altitude testing tapered off at the Santa Rosa sites. The agencies' joint testing at Eglin had been most active between January 1960 and July 1966. At the outset of 1967, the Air Force still planned two launch pads for Arcas firings. As of early 1970, the probe launch complex on Santa Rosa Island sustained facilities at Sites A-10, A-11, and A-15, with the probe launchers relocated to the easternmost section of the Bomarc area as Site A-15A. Eglin also supported two remote facilities for vertical probe launch: at Cape San Blas, Florida, and at Camp Tortuguero, Puerto

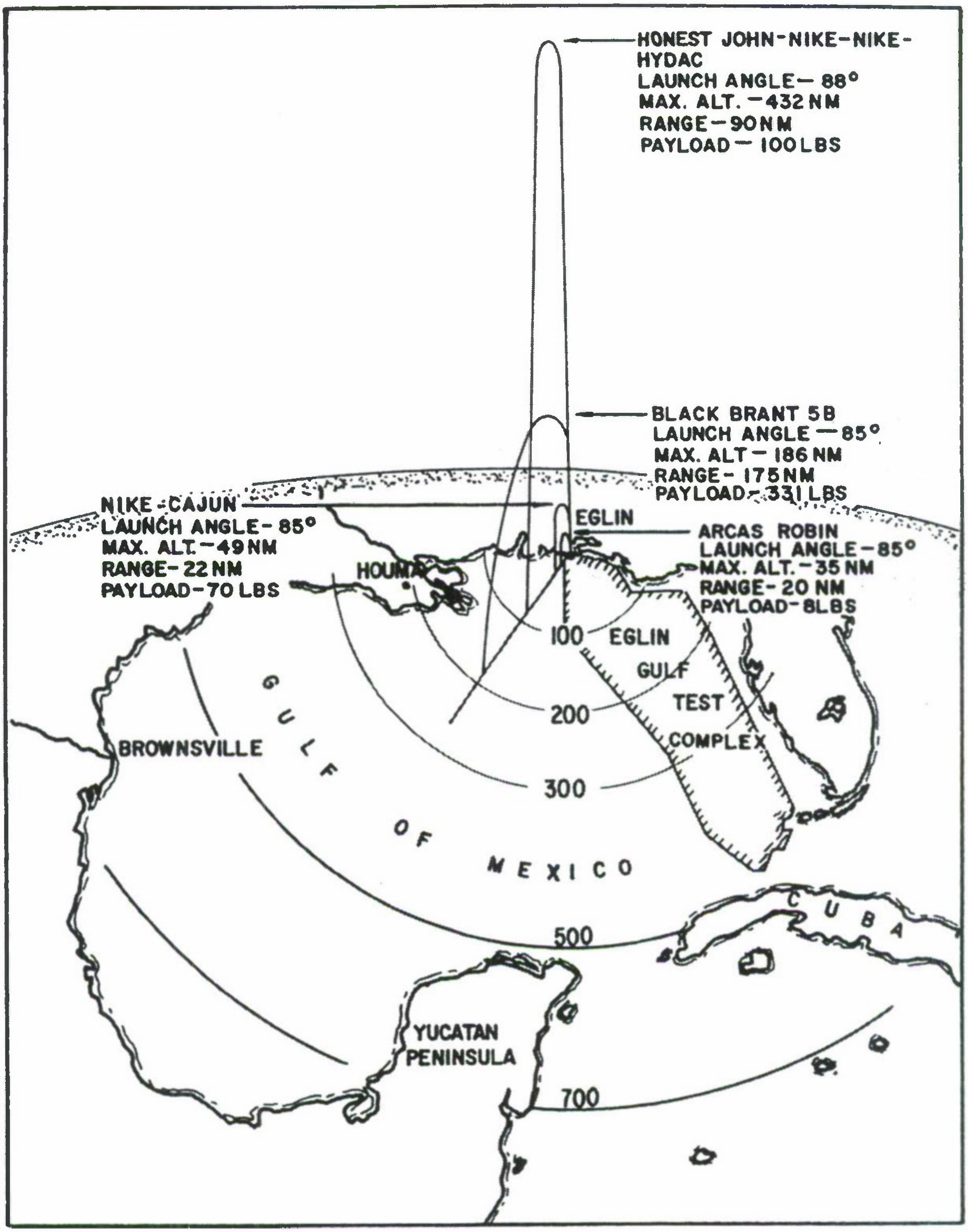

Plate 122: Typical Launch Trajectories over the Eglin Gulf Test Range from Santa Rosa Island, Eglin Air Force Base, 1972. In *History of the Armament Development and Test Center 1 July 1970 – 30 June 1971*, volume 3, part 1.

Rico. At Site A-15A personnel adapted two existing Bomarc launchers as Jason launchers, taking advantage of the Bomarc retractable roofs. The modified shelters permitted personnel to leave vehicles on the launchers for extended periods. By early 1972, the explosive safety officer for Eglin had approved full abandonment of the five launch pad areas at Site A-11, including their nine launchers of the 1960-1969 period.

Eglin also filled a complementary role to the Trinidad test site at the outset of the 1960s, with the Rome laboratories involved in at least one very significant NASA accomplishment of the period. The Site A-20 tracking station at Eglin, operational as of late 1957, assisted in Trinidad's BMEWS radar satellite tracking mission (Plate 123). Trinidad also featured a 30-foot antenna (see Plate 113) from which RADC personnel transmitted a voice message in 1960 to the NASA aluminized balloon satellite, Echo I (see Volume II, Chapter 12). Air Force personnel at Trinidad bounced their voice transmission off the satellite for reception at the RADC's Floyd Site in upstate New York (Plate 124). The 1960 Trinidad transmission using Echo I was the first international human voice reception from space for military purposes[193] (Plate 125).

Another ARDC / AFSC installation intertwined to some degree with NASA was that of the AFBMD and its follow-ons in Los Angeles (currently, Los Angeles Air Force Base).[194] The original responsibility of the AFBMD was to develop ICBMs for the Air Force under ARDC, but the Division acquired the added mission of R&D for the first military satellite system in February 1956. Within the AFBMD, a space mission became a priority with significant changes in 1961, 1967, 1979, and 1992 in how best to focus on its needs. As of September 1959, the DoD divided the responsibility for military satellite development between the Army, Navy, and Air Force. DoD assigned the mission of developing military communication satellites to the Army, while the Navy managed military

Plate 123: Site A-20 Tracking Station (Building 12722), Eglin Air Force Base, 1957. Photograph of May 2000. C. Dolan for EDAW, Inc.

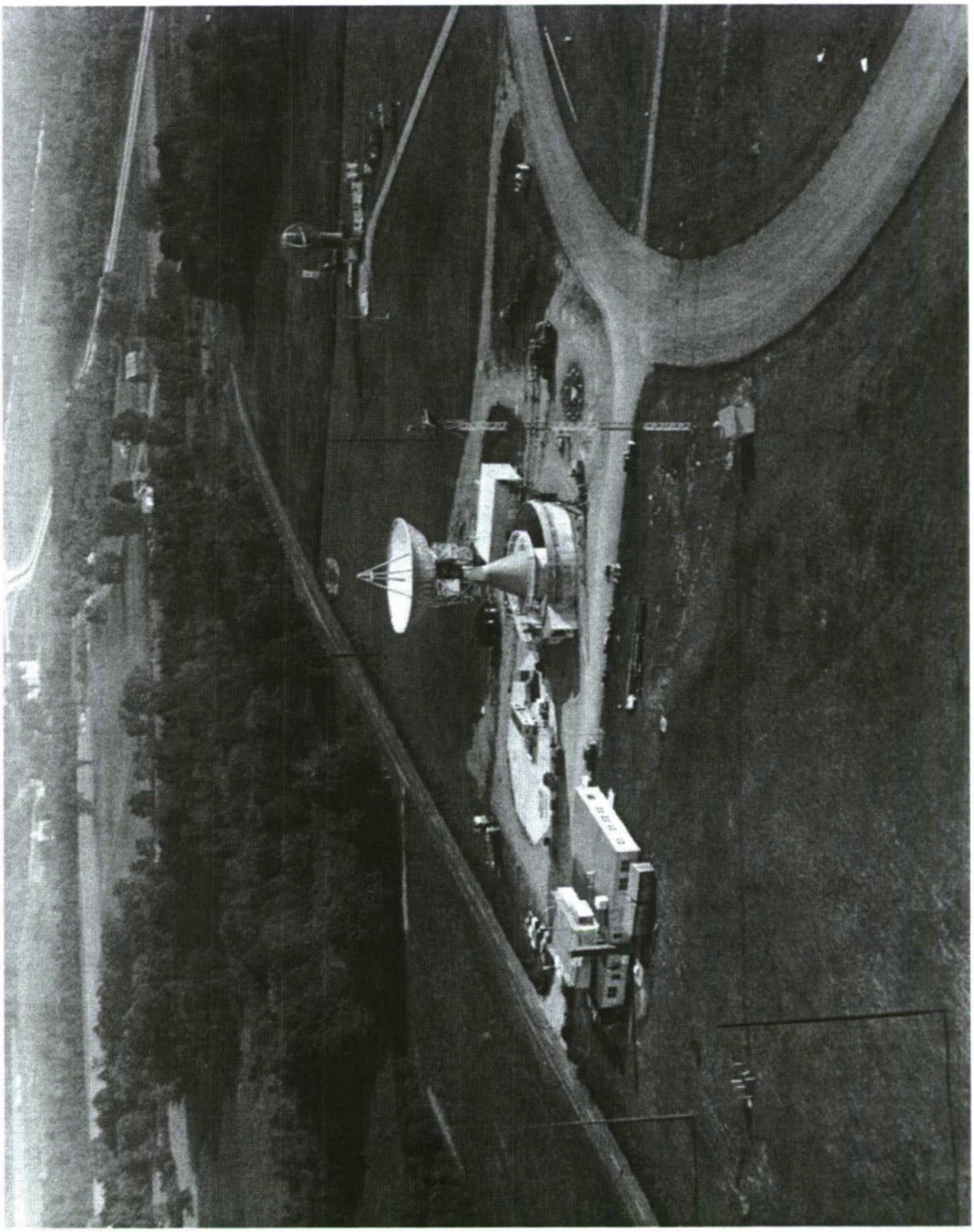

Plate 124: Rome Laboratories, Floyd Site, New York, 1950s-1960s. Undated photograph. Courtesy of the History Office, Rome Research Site, AFRL.

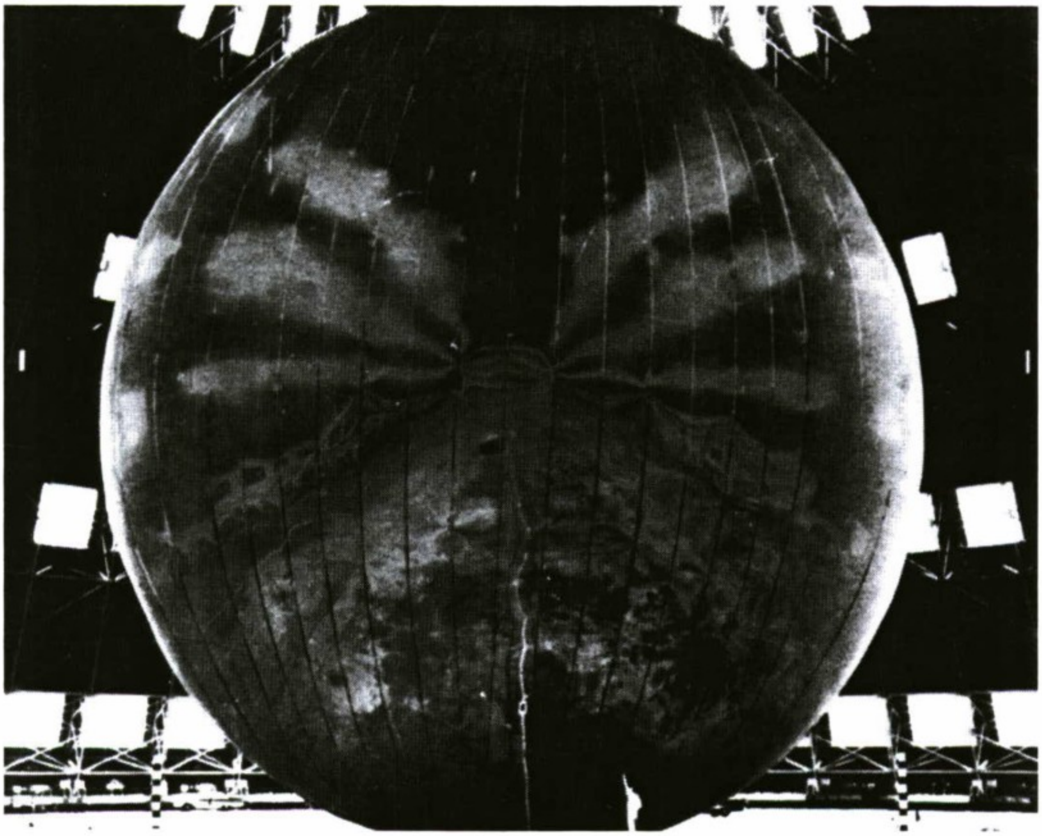

Plate 125: Echo I, 1960. Courtesy of the History Office, Rome Research Site, AFRL.

navigation satellites, and the AFBMD administered work toward reconnaissance and surveillance satellites. DoD also tasked the Air Force with developing and launching all military space boosters. As of March 1961, DoD turned more completely to the Air Force, placing nearly full responsibility for the development of military space systems in its jurisdiction and largely removing these missions from the Army and Navy. In 1970, the Air Force remained the primary agency "responsible for developing, producing, and launching space boosters and for developing, producing, and deploying satellite systems for missile warning and for surveillance of enemy nuclear delivery capabilities."[195]

The AFBMD (1957-1961) and Space Systems Division (1961-1967) first modified the Thor IRBM and the Atlas ICBM to serve as space boosters. Project Score achieved initial success for a space booster in December 1958. An Atlas modified through the AFBMD boosted an Air Force communications repeater into space that transmitted President Eisenhower's Christmas message. Modified Thor and Atlas missiles functioned as space-launch boosters throughout the Cold War, with Thor tasked in this mission into 1980 and Atlas until past the conflict's end. Through work done in the Space Systems Division and its successors, AFSC achieved families of standard launch vehicles based directly on the Thor and Atlas. These vehicles in effect became a structural framework for the American space program. NASA began using them as early as 1959, simultaneous with Air Force use of the Thor and Atlas launch vehicles to boost weather and communications satellites into space. In that year, NASA initiated development of the Delta upper stage launch vehicle for the Thor, as well as employed the Atlas as a standard launch vehicle for the agency from this date forward. NASA depended on Atlas for its first manned space program, Project Mercury, and relied on the ICBM for its orbital flights. In a similar manner, NASA used the Titan II boosters developed by the Space Systems Division to lift the capsules for Project Gemini into space from launch pads at Cape

Canaveral. The Air Force and NASA formally cooperated in the R&D for the space launch vehicles through a series of written agreements begun in 1959 and expanded during the 1960s. The Agena and Centaur upper-stage launch vehicles were some of the other programs in which the Space Systems Division sustained a strong developmental role.

Space Systems Division adapted the Titan as a booster for large, heavy payloads as of the middle 1960s, participating in the space shuttle program in the 1970s. The Air Force launched the first R&D Titan III in September 1964. The Titan family of launch vehicles included the Titan IIIB / Agena D, Titan IIID, and Titan IIIE / Centaur. NASA used the Titan IIIE / Centaur for the Viking mission to Mars. The agency employed the Titan III(34)D in the 1980s as a backup for the manned space shuttle. For the most part, NASA's reusable space shuttle replaced an expendable launch vehicle approach that was embodied by the Titan packages. The Space and Missiles Systems Organization (SAMSO, the follow-on of 1967-1979 to Space Systems Division) next contributed to the shuttle program. SAMSO developed and built to near-completion a space shuttle launch and landing site at Vandenberg Air Force Base (South Vandenberg) in 1979 for launch into polar orbit. The Space Systems Division had initiated work on the Vandenberg site for launch of a manned Air Force orbiting space laboratory more than a decade earlier, in 1965-1966. DoD had cancelled that program in 1969, leaving the site in suspended use until the NASA program of the 1970s. Although NASA also chose to forego use of the Vandenberg shuttle launch pad, its development had been a major SAMSO project. Space Division (the reorganization of SAMSO, 1979 to 1989) continued to be involved in NASA efforts after the space shuttle Challenger exploded during launch from Canaveral in January 1986—an event that, in addition to its tragic character, shifted the space launch program back to use of expendable launch vehicles based on ICBMs. The Titan III(34)D had significant launch failures at this time too, leading to the final Cold War position of developing a greater variety of expendable launch vehicles to assure continuance for the full program of space payloads.

Air Force R&D in aerospace medicine additionally contributed to NASA's man-in-space mission, with numerous achievements in aviation medicine from the immediate post-World War II years forward. The first efforts within ARDC had concentrated at Wright-Patterson Air Force Base, building upon Army R&D within the aeromedical laboratory established on base in 1934. A sizeable contingent of German aeromedical doctors and research assistants arrived at Wright Field through Project Paperclip. The work of these men and women helped to expand the field of space medicine. The Air Force placed a second large group of German doctors, also under Paperclip, at the Air Force School of Aviation Medicine at Randolph Air Force Base in San Antonio (see Volume I, Part III). In late 1948, the School of Aviation Medicine began to set up explicit space medicine projects. The next year, Dr. Hubertus Strughold, the leading German aeromedical specialist within the Paperclip group at Randolph, became the head of the newly created Department of Space Medicine at the school. The Air Force planned for a new School of Aviation Medicine to complement the research skills of the Germans and had initiated efforts toward a self-contained aeromedical center in August 1946. After long delay, the Air Force decided on Brooks Air Force Base, also in San Antonio, as the site of the state-of-the-art replacement for the existing School of Aviation Medicine. Master planning and the design of individual buildings for the medical complex continued to stall, however, and the Brooks School of Aviation Medicine was not under construction until 1956-1957. The school officially opened in 1959 as the Aerospace Medical Center under Air Training Command. Not until 1961, did the Aerospace Medical Center at Brooks fall under AFSC, then renamed the United States Air Force School of Aerospace Medicine (USAFSAM).

Air Force space medicine explicitly supporting NASA has numerous examples. In 1958, projects included the testing of a space cabin simulator at Randolph, while work toward astronaut capability in weightless and G-force environments continued at Wright-Patterson. As of 1959, space medicine programs at Randolph began to shift to new quarters at Brooks. Throughout the Cold War, the Air

Force and NASA made significant achievements tied to NASA's space missions through R&D accomplished at the Aerospace Medical Center and the USAFSAM at Brooks.[196] Experiments and testing supported the astronaut program, with Brooks providing medical evaluations of astronauts under contract to NASA. Brooks personnel evaluated conditions varying from zero gravity, to pure oxygen, radiation dosage, and biological contamination. The USAFSAM developed such items as the pressure suits required for astronaut activities conducted outside the capsule during the Apollo and Gemini projects. For the Apollo program and its successors, the USAFSAM developed space food and beverages, feeding systems, and hermetically sealed containers, additionally aiding in the design of an appropriate space capsule cabin environment. NASA refined the engineering of its capsules for manned space missions through pretests using biopacks developed at the USAFSAM. Biopacks had a variety of applied uses, including providing life support for mice and primates that NASA sent into space, and carrying experimental equipment and instrumentation. Brooks also contributed medical technologies to the Air Force development of the manned orbiting laboratory in the middle 1960s, for which the Space Systems Division in Los Angeles designed and built the Vandenberg launch pad. The manned orbiting laboratory effort, although aborted by the Air Force, substantially contributed to NASA's own orbiting research laboratory Skylab. In the 1970s, the USAFSAM conducted studies in decompression and nuclear survivability in continued support of NASA's space shuttle program. And as of 1975, NASA chose Brooks as a remote storage site for about 14 percent of the lunar rocks, pebbles, soil, and dust brought back by the Apollo astronauts during their six missions of 1969 to 1972.

Air Force – NASA efforts also went forward during the Cold War at Wright-Patterson, where work not only interlocked with the missions of its R&D installations at Edwards, Hanscom, Eglin, Rome, Los Angeles, and Brooks, but also broadly addressed certain aspects of basic space research as well as contributing specific projects of its own. The Zero Gravity program initiated through the Flight Test Division in 1957 is an example of Wright-Patterson's work. The Flight Test Division modified a KC-135 and C-131 to conduct the zero gravity tests. Pilots flew the planes in Keplerian trajectories (essentially parabolas) to simulate low or zero gravity conditions for periods of about 30 seconds. The achieved environment of weightlessness offered the most accurate simulation of actual space conditions during the early man-in-space developmental years. In the first six months of 1962, the Flight Test Division participated in 20 such zero gravity test programs at Wright-Patterson. The Division completely padded the test compartment of the KC-135 and installed lighting to film the experiments using handheld cameras. The first tests addressed studies of body maneuvers and the behaviors of fluids. Liquids that were boiled in a weightless environment, for example, proved to produce vapor bubbles rising perpendicularly from their heating element. Wright-Patterson's Flight Test personnel evaluated methods of crew transfer in zero gravity conditions in 1964 for the NASA Apollo and Gemini missions, as well as for Skylab. The tests included hatch openings and connective tunnels. Personnel installed full-scale mockups of the Apollo, Gemini, and Lunar Excursion cabins in the test aircraft in support of the crew transfer experiments. Additional tests featured tethered astronaut activity outside the spacecraft. Flight Test personnel also studied the Lunar Roving Vehicle in the modified aircraft environment. Men erected bumpers at each end of the aircraft cabin interior and secured the vehicle through a rope-and-braking device. Other personnel operated the vehicle through an electrical cable attached to its control stick, steering the vehicle over small obstacles set up in the aircraft to simulate the uneven lunar surface. By 1972, the Zero Gravity program had flown about 48,000 parabolas simulating weightless space flight.[197]

The Apollo Range Instrumentation Aircraft (ARIA) was a second major project conducted by Wright-Patterson for NASA. To meet the tracking and telemetry needs of the Apollo program, the Air Force developed a high-speed aircraft instrumented to acquire, track, and gather data on NASA vehicles during launch, as well as during their reentry into the earth's atmosphere. AIRA Aircraft operated internationally. The planes picked up and transmitted astronaut voices. They also recorded telemetry

data from manned and unmanned NASA and DoD space vehicles. The Air Force modified eight C-135 transport-cargo aircraft for ARIA, designating the specialty plane the EC-135N. McDonnell-Douglas and Bendix were the contractors for the program's aircraft modification and electronics equipment testing, while Electronic Systems Division at Hanscom was responsible for overall procurement. Personnel at Patrick Air Force Base operated and maintained the EC-135N for test and evaluation. ARIA became operational in January 1968. ARIA (renamed Advanced Range Instrumentation Aircraft after the completion of the Apollo program) transferred to Wright-Patterson in 1975 under the 4950th Test Wing. The EC-135N featured a seven-foot diameter telemetry antenna housed within a 10-foot radome in the nose of the aircraft, which gave the plane a distinctive appearance. DoD used ARIA in support not only of NASA missions, but also to provide telemetry for ICBM and satellite launch-and-reentry. The ARIA program was a long-lived one during the Cold War. In 1982, the Air Force replaced the original EC-135Ns with eight modified Boeing 707-320C / CF planes, designating the new aircraft the C-18. The 4950th Test Wing at Wright-Patterson received the first of the C-18s in February. During 1984, the 4950th Test Wing modified the C-18s into EC-18s. Wing personnel reconfigured the new ARIA as six EC-18s and two EC-135Es (additionally equipping the two EC-135Es for cruise missile testing). At the end of the Cold War, ARIA supported NASA's Galileo mission to orbit Jupiter (1989), its Magellan mission to map the planet Venus (1990), and its Pegasus missions to carry military payloads into earth orbit (a three-stage launch from a NASA B-52 based at Edwards [1990 and 1991]). In 1990, ARIA also participated in the two NASA shuttle missions of Atlantis and Discovery.[198]

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[1] The Air Ministry, *Fighter Control and Interception*, volume 5 of *Signals* (London: The Air Ministry, 1952), 5-7.

[2] *Ibid*, 7-15.

[3] *Ibid*, 21, 23-24.

[4] *Ibid*, 28-30.

[5] *Ibid*, 32.

[6] *Ibid*, 42.

[7] *Ibid*, 45-54.

[8] Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense 1945-1960* (Washington, D.C.: Office of Air Force History, 1991), 24-29.

[9] Skidmore, Owings & Merrill would also design the Fighter Control Center that followed next in the sequence of required air defense infrastructure for World War II. Headquarters First Air Force, *History of the I Fighter Command December 1941 – July 1944 Part III*, volume 1 (Mitchel Field: First Air Force, February 1946), 200.

[10] Schaffel, *The Emerging Shield*, 1991, 30-36.

[11] Fourth Air Force, *Defense Plans and Operations of the Fourth Air Force, 1942-1945*, Fourth Air Force Historical Study No. III-2, volume 1, 18-20.

[12] *History of the I Fighter Command December 1941 – July 1944 Part III*, volume 1, 194.

[13] *Ibid*, 73, 195-198.

[14] *Ibid*, 199-200.

[15] *Ibid*, 210-212.

[16] *Ibid*, 216.

[17] *Ibid*, 230-234.

[18] *Ibid*, 279, 289.

[19] I Fighter Command, "History of I Fighter Command," typescript, 8 January 1944.

[20] Fourth Air Force, Rescue and Defense Section, "Project History," three-page typescript describing the VHF Systems Control Project, undated, document 128, in *Defense Plans and Operations of the Fourth Air Force, 1942-1945*, volume 4.

[21] IV Fighter Command, Headquarters: "VHF Control Systems Project," 13-page typescript, 31 August 1942, document 113, and, "VHF Control Net Systems Project, IV FC," eight-page typescript, 3 April 1943, document 115, both in *ibid.*

[22] "Status Report—Radio Sub-section, 26 June to 3 July inclusive," memorandum to the Signal Officer, IV Fighter Command, Oakland, 7 July 1943, document 118, in *ibid.*

[23] Paul E. Shanahan, Colonel, Air Corps, "Fighter Control Equipment on West Coast," memorandum to the Commanding General, Fourth Air Force, San Francisco, 20 June 1944, in *ibid.*
[24] George E. Rohde, 1st Lt., AGD (Adjutant General Department), "Fighter Control Equipment on West Coast," memorandum to the Commanding General, Air Service Command, 15 July 1944, document 121, in *ibid*; Lt. General Elwood R. Quesada, *History of Operation Greenhouse 1948-1951 (Joint Task Force 3)*, 11; and, "Lookout Mountain Laboratory," www.vce.com/LookoutMt.html.
[25] Howard E. Engler, Colonel, General Staff Corps, "Designation of Control Centers and Stations Operating Thereunder," memorandum to the Commander, each Main Base, each Control Group, 5 February 1945, document 124, in *ibid.*
[26] *Defense Plans and Operations of the Fourth Air Force, 1942-1945*, volume 1, 59-71.
[27] Four of the nine Fighter Control Centers remained unbuilt. Physical locations planned as of 28 December 1942 were: (1) on government property near Bangor, Maine; (2) near Portland, Maine; (3) near Burlington, Massachusetts; (4) on government property near Falmouth, Massachusetts; (5) on government property near Windsor Locks, Connecticut; (6) on government property near Mitchel Field, Long Island; (7) on government property at Fort Dix, New Jersey; (8) on government property at Camp Springs, Maryland; and, (9) on government property at Langley Field, Virginia. Details are included in First Fighter Command, Headquarters, "VHF Control Systems Project," 28 December 1942, 21-page typescript in *History of the I Fighter Command December 1941 – July 1944 Part III*, volume 4. By late May 1943, I Fighter Command had further refined these nine locations as (1) the vicinity of Dow Field, Bangor, Maine; (2) the vicinity of Portland, Maine; (3) adjacent to Bedford Airport, Bedford, Massachusetts (the future Hanscom Air Force Base); (4) Camp Edwards, Falmouth, Massachusetts; (5) on or near Bradley Field, Windsor Locks, Connecticut; (6) Roslyn, New York; (near Mitchel Field) (7) Fort Dix, New Jersey; (8) Camp Springs, Maryland (the future Andrews Air Force Base); and, (9) Langley Field, Virginia (the future Langley Air Force Base). These projections are included in I Fighter Command, Headquarters, "Housing Construction for VHF Control Systems Project," memorandum to the Commanding General, First Air Force, Mitchel Field, 24 May 1943, in *ibid.*
[28] *Ibid*, 279-283.
[29] *Ibid*, 276, 293.
[30] *Ibid*, 283-284.
[31] *Ibid*, 293.
[32] Wilson N. Durham, Lt. Col., Air Corps, "VHF Progress Report 1 June to 30 June 1944," memorandum to the Commanding General, I Fighter Command, 4 July 1944, in *History of the I Fighter Command December 1941 – July 1944 Part III*, volume 4.
[33] *Ibid*; IV Fighter Command, Headquarters, "Code Designation of Fighter Control System SCS-2 Stations," memorandum, 21 April 1943, document 116, in *Defense Plans and Operations of the Fourth Air Force, 1942-1945*, volume 4.
[34] Central Air Defense Force, *History of the 31st Air Division (Defense) 1 July – 31 December 1953*, volume 1.
[35] Karen J. Weitze, *Inventory of Cold War Properties: Andrews, Charleston, Dover, Grand Forks, McChord, Scott, and Travis Air Force Bases* (Plano, Texas: Geo-Marine, Inc., for Air Mobility Command, October 1996).
[36] Karen J. Weitze, *Cold War Infrastructure for Air Defense: The Fighter and Command Missions* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 79-90. Information and analysis presented in *Cold War Infrastructure for Air Defense* was the author's second attempt to pull together the correct facts for the design and engineering of the Holabird, Root & Burgee ADCC and ADDC. While the basic history is correct, additional research during 2000 and 2001 has added considerable information to the story—changing some of the assumed details. The work presented here supercedes previous efforts.
[37] North American Air Defense Command, *Fifteen Years of Air Defense*, Historical Reference Paper No. 5 (Ent Air Force Base: North American Air Defense Command, December 1962).
[38] Thomas A. Sturm, Directorate of Historical Services, Office of Information Services, *Organization and Responsibility for Air Defense March 1946 – September 1955.* Of note, Type 2 and Type 4 Operations Buildings also existed at Eglin Air Force Base, under construction as of very late 1952. Although these structures were identical to the Holabird, Root & Burgee air defense command posts designed in 1949, they did not function as a traditional ADDC and ADCC pair and are unique nationwide. The pair served as an Air Operations Center for electronics and radar testing done at Eglin (typically carried out through the Rome Air Development Center, and sometimes involving teams at the Cambridge Research Laboratories). Construction of the Type 2 and Type 4 Operations Building coincided with the designation of the Air Force Operational Test Center at Eglin from July 1953 to February 1958. This test center, while integral to Air Force R&D, was not

subsumed under ARDC. Instead, the center functioned within Air Proving Ground Command at Eglin, with a mission linked to operational suitability testing. (See Volume I, Plate 16.) The Air Force Operational Test Center featured an Air Defense Division composed of three branches: the Interceptor Branch, the AC&W Branch, and the Special Projects Branch. Radar and fighter aircraft tests included ones for state-of-the-art American equipment in development, as well as tests of captured Soviet materiel. The latter is especially interesting. A Wurzburg radar, used by the Germans during World War II and adapted for application in the Soviet Union as of 1952, was one such example. Another involved testing a captured MiG-15 against American air defense and combat systems during 1954. The Center also ran comparison tests to the F-86F. Other divisions of the Air Force Operational Test Center included Tactical and Strategic Air Divisions, an Electronics Division, and a Nuclear Weapons Division. Illustrative of the overlap between Air Proving Ground Command and ARDC, the Nuclear Weapons Division of the Air Force Operational Test Center had a detachment stationed at Kirtland Air Force Base in New Mexico. For more detailed discussions of the Air Force Operational Test Center, see Volume II, Chapter 4 (Eglin) and Chapter 8 (Kirtland).

[39] Archival records for the numbered air defense areas are complex, with complete holdings at the Air Force Historical Research Agency at Maxwell Air Force Base, Montgomery, Alabama. Each air defense area, including its assigned military units, is catalogued through its number, with the designations always referenced as "Air Division (Defense)." For example, records for the 25th Air Defense Area exist as quarterly and semiannual histories of the 25th Air Division (Defense), by year. Individual Air Division (Defense) histories are not listed here, unless quoted from directly. All dates included in the discussions of individual Air Divisions (Defense) are taken from these histories.

[40] Headquarters United States Air Force, *History of the Directorate of Operations 1 January – 30 June 1956*, volume 2, inclusion 1: "The Ground Observer Corps," 3 and appended map.

[41] Headquarters Continental Air Command, "Construction Priorities, Permanent Air Control and Warning System," memorandum of 4 January 1950, document 78, *Supporting Documents*, volume 4 of *A History of the Work of the Air Defense Command and its Predecessors through June 1951.*

[42] *History of the 31st Air Division (Defense) 1 July – 31 December 1953*, volume 1, 447.

[43] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 79-105. Includes detailed, footnoted discussion of the American air defense system through the end of the Cold War.

[44] Drawings held in the civil engineering vault at Wright-Patterson Air Force Base.

[45] Paige Peyton (Earth Tech) and Rainshadow Associates, *Determination of Eligibility Building 602 Richards-Gebaur Air Force Base, Missouri* (Colton, California: The Earth Tech Corporation, with Rainshadow Associates, February 1994). The document contains selected factual information of note, but must be used with care. The authors did not understand the complex air defense program of ADC, nor the role of ADCCs and ADDCs, during the 1949-1956 period. Conflated information is at times misleading.

[46] Continental Air Defense Command, *Air Defense of Alaska 1940-1957*, Historical Reference Paper Number Two, ca. 1957, 24-25.

[47] 41st Air Division (Defense), *Historical Report 1 January – 30 June 1954*, 3. Johnson Air Base is not to be confused with Johnson Island, or with Yokota Air Base. Johnson Air Base was a distinct installation in the immediate vicinity of Yokota.

[48] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 90-105. See especially discussion and endnotes, page 97.

[49] Air Defense Command, *History of Joint 26th Air Defense Division and 26th Air Division (Defense) January – June 1956*, 30-32.

[50] Air Defense Command, *4620th Air Defense Wing (Experimental SAGE) 1 June 1955 – 30 June 1958*, 2-12.

[51] Air Defense Command: *History of the Air Defense Command 1 January – 30 June 1961*, 130, and, *Historical Record of the Oklahoma City Air Defense Sector (Manual) 31 March 1960*, 1.

[52] Mr. Kernus and Mr. Markowitz, "1st with Fallout Protection," *Air Force Civil Engineer* 4, 2 (May 1963): 16-17.

[53] *History of the Air Defense Command 1 January – 30 June 1961*, 104-105, 129.

[54] Richard F. McMullen, *Command and Control Planning 1958-1965*, ADC Historical Study No. 35, volume 1, 15ff.

[55] The number of BUIC I sites is alternately noted as 27 and 25. See *ibid*, 33-37.

[56] Primary analysis of the BUIC I and II system is derived from *Command and Control Planning 1956-1965* and from drawings of Type 2 Operations Buildings modified for BUIC in the personal collection of Karen J. Weitze.

[57] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1965*, 29.
[58] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1966*, 12.
[59] 552nd AEW&C Wing Information Office, "Air Defense and the 552nd AEW&C Wing," four-page typescript in the History Office, McClellan Air Force Base. (The History Office closed with McClellan in 2000-2001.) Also, Maurice A. Miller (ed.), *McClellan Air Force Base 1936-1982* (McClellan Air Force Base: Office of History, Sacramento Air Logistics Center, 1982), 115-117.
[60] McMullen, *Command and Control Planning 1956-1965*, ca.1965, 41-45.
[61] Schaffel, *The Emerging Shield*, 1991, 266; Bernard Blake (ed.), *Jane's Radar and Electronic Warfare Systems Seventh Edition 1995-1996* (Great Britain: Thomson Publishing Company, 1995), 34.
[62] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 104-105, 129.
[63] A full set of the Holabird, Root & Burgee drawings for Area D exists in the civil engineering vault at Tinker Air Force Base. These drawings are rare, especially when surviving in this state of completeness. All particular analysis of the Holabird, Root & Burgee buildings derives from previous work by the author, supplemented by a review of the drawings at Tinker.
[64] Diane Shaw Wasch, Perry Bush, Keith Landreth, and James Glass, *World War II and the U.S. Army Mobilization Program: A History of 700 and 800 Series Cantonment Construction* (Washington, D.C.: Historic American Buildings Survey (HABS) / Historic American Engineering Record (HAER), National Park Service, ca.1988-1989); and, John S. Garner, *World War II Temporary Military Buildings: A Brief History of the Architecture and Planning of Cantonments and Training Stations in the United States*, USACERL Technical Report CRC-93/01 (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, March 1993).
[65] Air Defense Command, *History 33rd Air Division (Defense) 1 July – 31 December 1955*, volume 1, 1.
[66] *Ibid*, 2, 5.
[67] *Ibid*, 43.
[68] Complete drawings showing modifications over time exist in the civil engineering vault at Tinker Air Force Base.
[69] *Ibid*.
[70] See the bibliography in volume II for a listing of pertinent individual drawings.
[71] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 188.
[72] Air Defense Command, *History 33rd Air Division (Defense) 1 January – 30 June 1956*, volume 1, 11, 26. Also, drawings, civil engineering vault, Tinker Air Force Base.
[73] Drawings, civil engineering vault, Tinker Air Force Base.
[74] Air Defense Command, *History of the 33rd Air Division (Defense) 1 October – 31 December 1959*, 1.
[75] Karen Lewis, Katherine J. Roxlau, Lori E. Rhodes, Paul Boyer, and Joseph S. Murphey, *Historic Context and Methodology for Assessment*, volume 1 of *A Systemic Study of Air Combat Command Cold War Material Culture* (Austin: Mariah Associates, Inc., for Air Combat Command, December 1995), 90-92.
[76] Air Defense Command, *History of 32nd Air Division (SAGE) 1 January – 31 December 1960*, volume 1, 1-19, 25-41.
[77] Drawings, civil engineering vault, Tinker Air Force Base.
[78] Jean Martin, *32nd Air Division (SAGE): The Air Defense Build-Up in Southern Florida, A Historical Study January – December 1961*, appended to *History of the 32nd Air Division (SAGE) January – June 1961*, volume 1.
[79] Drawings, civil engineering vault, Tinker Air Force Base.
[80] *Historical Record of the Oklahoma City Air Defense Sector (Manual) for the period ending 31 March 1960*, 1, and, appended General Orders.
[81] Schaffel, *The Emerging Shield*, 1991, 262.
[82] *Phasing Plan for the Reconfiguration of the 32nd Air Division (28 July 1960), Revised to May 1961*, in *History of the 32nd Air Division (SAGE) January – June 1961*, volume 2.
[83] Jamesway hutments carried an "equipment" designation, that of the S-80.
[84] Multiple detailed supporting documents and communications of the 32nd CONAD Region headquarters and the 32nd Air Division (SAGE), in Headquarters 32nd Air Division (SAGE), *32nd Air Division (SAGE) & 32nd CONAD Region in Cuban Crisis October – December 1962*, volume 2.

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[85] 32nd CONAD Region, 32nd CONAD Region OPLAN 2-62, five-page typescript, 27 October 1962, document 59 in *ibid.*

[86] Air Defense Command, *Historical Record of the Oklahoma City Air Defense Sector for the period ending 30 September 1963*, 1.

[87] Engineering Installation Center History Office: "Organizations Headquartered at Oklahoma City Air Force Station 1951-1985," one-page discussion of organizations, 7 February 1985; and, "Oklahoma City Air Force Station (OCAFS)," one-page outline of chronology, 19 March 1991. Each of these summaries is useful, but contain errors and / or misleading statements.

[88] Bernard J. Termena, Layne B. Peiffer, and H.P. Carlin, *Logistics: An Illustrated History of AFLC and Its Antecedents, 1921-1981* (Wright-Patterson Air Force Base: Office of History, Air Force Logistics Command, ca.1981), 144-145.

[89] Engineering Installation Center, Office of History, "History of the Southern Communications Area / Engineering Installation Center," three-page typescript, ca.1983.

[90] Historians Dr. Cecil Trice of the Air Force Communications Agency, Engineering Installation Center, Tinker Air Force Base, and, Larry Morrison, Air Force Communications Agency, headquarters, Scott Air Force Base, provided the lineage of SCA from its inception in the late 1930s within the Army, forward to 2000. The agency began as the Army Airways Communications System under the United States Army, Directorate of Communications, in 1938. In 1943, the Army Airways Communications System evolved into the Army Airways Communications Wing as a part of Flight Control Command within the Army Air Forces. The next year, the Wing became the Army Airways Communications System. In 1946, two name changes occurred: first to the Army Airways Communications Service, and later the same year to the Airways and Air Communications Service—a name sustained with slight modification into July 1961. When the Air Force achieved independence from the Army in 1947, the Air Communications Service followed directly from Army Air Forces to the Air Force as the Air Force Communications Service (AFCS). GEEIA entered the picture in 1958, keeping this name until 1979. SCA emerged from a combination of GEEIA and AFCS units. In 1979, AFCS became AFCC, changing again in May 1993 to AFC^{4}A. "C^4" referred to the agency's role in command, control, communications, and computers. As of mid-1996, the agency was again simplified to the Air Force Communications Agency. Over time, headquarters locations for the Army-Air Force agency were at Bolling (1943); Ashville, North Carolina (May 1943); Langley (December 1945); Gravelly Point, Virginia (December 1946); Andrews (November 1948); Scott (January 1958) [with GEEIA first at Wright-Patterson, and then at Griffiss at this same time]; Richards-Gebaur (July 1970); and, Scott (November 1977 through today).

[91] A detailed discussion of FIS infrastructure is presented in Weitze, *Cold War Infrastructure for Air Defense*, 1999, 19-78. Information offered here without endnotes is documented in this study.

[92] "New Alert Hangar for USAF," *Aviation Week* 58, 24 (15 June 1953): 22.

[93] Only one instance is known of a double squadron in two separate alert hangars, with two distinct alert aprons on opposite sides of the same end of a runway: at Sioux City Air Force Base in Iowa. Mapping and aerial photographs suggest that the situation at Sioux City was somewhat makeshift, with one of the hangars a standard Strobel & Salzman structure and the other an *ad hoc* unit not fitting any known pattern.

[94] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 115-116.

[95] "Deployment of Air Defense Radar – April 1950 (Lashup)," map in Air Defense Command, *The Air Defense of the United States: A History of the Work of the Air Defense Command and its Predecessors through June 1951*, volume 1. A "fighter alert" squadron also existed at Eglin Air Force Base from about May 1951. The 3200th Fighter Test Squadron functioned as a part of the 3200th Proof Test Wing / Group. The squadron dates to July 1948, and as of mid-1949 had an underground scramble hut at the end of the primary Eglin runway. As yet, the scramble hut has no known comparisons at other Air Force installations. Eglin expanded the hut as alert ready crew quarters in 1951 for air defense equipment testing. The mission of the 3200th Proof Test Wing / Group is the precursor to that of the Air Force Operational Test Center of mid-1953. See Note 38.

[96] Untitled memorandum from the Chief of Staff, United States Air Force, to SAC, MATS, and Headquarters, COMD, Bolling AFB, July 1950, in *ibid*, volume 4 (supporting documents).

[97] Analysis presented here derives from previous studies by the author; drawings in the civil engineering vaults at each of the current AFMC installations, as well as those in the author's private collection; and, field visits to the AFMC bases between 1999 and 2001.

[98] Bases considered here are only those that today remain within AFMC. Other ARDC / AFSC and Air Materiel Command / AFLC installations supported FIS alert, although the author has not evaluated the extent of this phenomenon. For example, Holloman Air Force Base in New Mexico sustained very late alert under TAC,

and has an unusual alert hangar (as interpreted via aerial photographs). Clinton County Airfield in Ohio, an early installation associated with ARDC, became a dispersal location for FIS from Lockbourne Air Force Base in Columbus in 1969. Patrick also supported FIS in a late period, and shows the remnants of a fighter alert apron and taxiway on Air Force master plans of 1957.

[99] *History 33rd Air Division (Defense) 1 January – 30 June 1956*, volume 1, 2.

[100] Diane Williams, analysis of drawings in the civil engineering vault at Kirtland Air Force Base; and, Karen Weitze, field work at Kirtland of 1996, 1999, and 2000.

[101] 2750th Air Base Group, *History of Wright-Patterson Air Force Base 1 January – 30 June 1951*, 60.

[102] "PT. of Area 'C' W-P. A.F.B. Building Plan," baseline date 2 February 1945, updated to September 1949, and, "U.S. Army Air Forces Wright Field Areas 'A' & 'D.' Areas Occupied by 97th Fighter Squadron," baseline date 15 January 1945, updated to March 1951: two folded maps in File "56th Fighter-Interceptor Squadron & 97th FIS," Box "WPAFB Former Units, History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

[103] Sets of drawings for both the Strobel & Salzman hangar and the Butler hangar exist in the civil engineering vaults at Kirtland and Wright-Patterson Air Force Bases. In the case of Wright-Patterson, ADC apparently first planned to build the Strobel & Salzman hangar, but was likely financially constrained and turned to the Butler hangar to move the project along. At Kirtland, the situation may have been similar, but it is also possible that consideration of the Strobel & Salzman hangar occurred in 1953-1954 in response to the need to relocate the FIS alert area at the end of the newly lengthened runway.

[104] Drawings, civil engineering vault, Wright-Patterson Air Force Base.

[105] Butler Manufacturing Company, *Load Test 70-13 Aluminum Rigid Frame Arctic Alert Hangar, United States Air Force, Wright-Patterson Air Force Base, Contract No. AF33(038)-20305, Date of Test May 25, 1951* (Kansas City, Missouri: Butler Manufacturing Company, 1951).

[106] Wright-Patterson Air Force Base Planning Board, "Minutes of Planning Board Meeting," 19 January 1956. In File "Minutes, WPAFB Planning Board, 1956," Box "Base Planning Board 1948-1958," History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

[107] *Ibid*, 16 August 1956. Discussion of "Hi Card Package, FY-1958."

[108] Drawings, civil engineering vault, Wright-Patterson Air Force Base.

[109] Drawings, civil engineering vault, the former Griffiss Air Force Base (now, converted to a business park); and, field analysis, July 2000.

[110] Cambridge Research Center, *History of the Cambridge Research Center 1 January – 30 June 1952*, volume 16, part 1, 66-67.

[111] Drawings, civil engineering vault, Hanscom Air Force Base. The ADC FIS complex of four buildings was under construction in 1954.

[112] Air Defense Command, *49th Fighter Interceptor Squadron (ADC) History 1 July – 31 December 1956.*

[113] Air Defense Command, *49th Fighter Interceptor Squadron (ADC) History 1 January – 30 June 1957.*

[114] Air Defense Command: *49th Fighter Interceptor Squadron (ADC) History 1 June – 31 December 1958*; and, *Historical Record of the 49th Fighter Interceptor Squadron (ADC) for the period ending 31 March 1959.*

[115] Photographs of four F-106s on alert for the 329th FIS, in the collections of the History Office, Edwards Air Force Base. See Volume II, Chapter 3.

[116] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 219-224. The author has previously addressed TAC alert at Eglin in detail in this study. Undocumented facts herein are referenced fully in this earlier work, while new information is provided endnotes.

[117] Martin, *32nd Air Division (SAGE): The Air Defense Build-Up in Southern Florida*, 1961, 8.

[118] *Ibid*, 2, 14-15, 19, 23.

[119] *Ibid*, 36.

[120] *Historical Record of the 331st Fighter Interceptor Squadron (ADC), Webb AFB, Texas, for the period ending 31 December 1962*, document 38 in *32nd Air Division (SAGE) & 32nd CONAD Region in Cuban Crisis October – December 1962*, volume 2.

[121] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 107-123. Again, the author has previously addressed SAC alert infrastructure in detail. Undocumented facts herein are referenced fully in this earlier work, while new information is provided endnotes.

[122] Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 of *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989), *passim*. Mueller includes the inclusive dates for SAC Wings on alert at each installation.

[123] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 180-189; also, Karen J. Weitze, Lori Lilburn, Christy Dolan, and Angie Gustafson, Buildings 1315, 1326, 1328, 1343, 1344, 1345, 1351, 1352, 1353, and 1355, *Eglin Air Force Base: Inventory of Historic Properties FY 2000* (San Diego: EDAW, Inc., for Air Force Materiel Command, July 2001).
[124] Mueller, *Active Air Force Bases*, 1989, *passim*.
[125] Headquarters United States Air Force, *History of the Directorate of Installations 1 July – 31 December 1958*, 84.
[126] Mueller, *Active Air Force Bases*, 1989, *passim*; Strategic Air Command, *History of Headquarters Strategic Air Command 1961*, SAC Historical Study No. 89, 187-189; Strategic Air Command, "Construction Schedules," item 20, *History of Strategic Air Command June 1958 – July 1959*, SAC Historical Study No. 76, volume 8.
[127] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 172-174. Discussion of the Hound Dog – Quail at Eglin is taken from this preexisting study.
[128] The Hound Dog munitions structures are not yet evaluated in the historic inventory at Eglin Air Force Base.
[129] Jack Reise, *Tinker Air Force Base: A Pictorial History* (Tinker Air Force Base: Air Force Logistics Command, 1983), 70, 73-74.
[130] Strategic Air Command, *History of the 4137th Strategic Wing (SAC) 1 July – 31 December 1959*, 9.
[131] Strategic Air Command, *History of the 4137th Strategic Wing (SAC) 1 January – 30 June 1960*, 23.
[132] The SAC alert area is sited as three slightly distinct physical sites, near one another, with one discontiguous structure located separately on base. Analysis is made based on review of drawings (on microfiche cards) at the civil engineering drawings vault, Robins Air Force Base, and, on field trips to the installation in February and October 2000. For detailed confirmation of the Hound Dog / Quail storage structures, also see *ibid*, 24.
[133] *History of the 4137th Strategic Wing (SAC) 1 January – 30 June 1960*, 27.
[134] Strategic Air Command, *History of the 4137th Strategic Wing (SAC) 1 July – 30 September 1960*, 35-38.
[135] Strategic Air Command: *History of the 4137th Strategic Wing (SAC) 1 October – 31 December 1960*, 55-60; *History of the 4137th Strategic Wing (SAC) 1 February – 31 March 1961*, 47-51.
[136] *History of the 4137th Strategic Wing (SAC) 1 February – 31 March 1961*, 28-31.
[137] Strategic Air Command, *History of the 4137th Strategic Wing (SAC) 1 May – 31 July 1961*, 20.
[138] Strategic Air Command: *History of the 4137th Strategic Wing (SAC) 1 February – 31 March 1961*, 50-51; *History of the 4137th Strategic Wing (SAC) 1 May – 31 July 1962*, 55.
[139] Strategic Air Command, *History of the 4137th Strategic Wing (SAC) 1 August – 31 October 1962*, 29-36.
[140] Strategic Air Command, *History of the 4043rd Strategic Wing (SAC) 1 January – 31 December 1960*, 125; also, field work and drawings analysis at Wright-Patterson Air Force Base, August and November 2000.
[141] *History of the 4043rd Strategic Wing (SAC) 1 January – 31 December 1960*, 126-128.
[142] Analysis of drawings in the civil engineering vault at Wright-Patterson Air Force Base.
[143] Strategic Air Command, *History of the 4043rd Strategic Wing (SAC) 1 – 31 January 1961*, 44.
[144] *Ibid*, 8-9, 43-46.
[145] Strategic Air Command: *History of the 4043rd Strategic Wing (SAC) 1 – 28 February 1961*, 30-34; *History of the 4043rd Strategic Wing (SAC) 1 – 30 April*, 12-13.
[146] Strategic Air Command, *History of the 4043rd Strategic Wing (SAC) 1 – 31 March 1961*, 18-23.
[147] Strategic Air Command, *History of the 4043rd Strategic Wing (SAC) 1 – 30 April 1961*, 3-4, 11-14, 18.
[148] Strategic Air Command, *History of the 4043rd Strategic Wing (SAC) 1 – 31 October 1961*, 6-7.
[149] Strategic Air Command, *History of the 4043rd Strategic Wing (SAC) 1 – 31 October 1962*, 3-7.
[150] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 122-123.
[151] Henry Narducci, *Guide to Strategic Air Command Histories*, binder and electronic document, History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.
[152] Many of the SAC histories remain classified for the period of the late 1960s into the middle 1970s. However, selected volumes of supporting documents are declassified and offer information for SAC satellite alert. The initial plan for SAC dispersal bases is derived from a memorandum for "Force Dispersal Communication Packages, American Telephone and Telegraph Company," 23 March 1967. "A" bases are listed as: Boeing Field, Seattle; Cecil Naval Air Station, Florida; Dulles Airport, Washington, D.C.; Edwards Air Force Base, California; Eglin Air Force Base, Florida; Forbes Air Force Base, Kansas; Hunter Army Air Field (formerly, Air Force Base), Georgia; JFK Airport, New York; JFK Memorial Airport, Florida; Lemoore Naval Air Station, California; Lincoln Air Force Base, Nebraska; Logan Airport, Massachusetts; Oceana Naval Air Station, Virginia; Seattle-Tacoma Airport, Washington; Schilling Air Force Base, Kansas; Sheppard Air

Force Base, Texas; and, Tinker Air Force Base, Oklahoma. "B" bases are listed as: Bergstrom Air Force Base, Texas; Bradley Field, Connecticut; Campbell Air Force Station (Fort Campbell), Kentucky; Detroit Airport, Michigan; Dobbins Air Force Base, Georgia; Duluth Air Force Station, Minnesota; Elmendorf Air Force Base, Alaska; Fallon Naval Air Station, Nevada; General Mitchell Field, Wisconsin; Pittsburgh Airport, Pennsylvania; Hill Air Force Base, Utah; Lambert Airport, Missouri; McCarren, Nevada; McChord Air Force Base, Washington; McClellan Air Force Base, California; MacDill Air Force Base, Florida; McGuire Air Force Base, New Jersey; the Minneapolis-St. Paul Airport, Minnesota; Mountain Home Air Force Base, Idaho; Oakland Airport, California; O'Hare Airport, Illinois; Otis Air Force Base, Massachusetts; Palmdale Airfield, California; Patuxent River Naval Air Station, Maryland; "Phelps Collins," Michigan; Port Columbus, Ohio; and, Walker Air Force Base, New Mexico. Documented in: Strategic Air Command, *History of Strategic Air Command July – December 1967*, SAC Historical Study No. 110, volume 5.

[153] "Dispersal Bases," tables for revisions A, B, and C, in *History of Strategic Air Command July – December 1967*, SAC Historical Study No. 110, volume 6.

[154] Strategic Air Command, *History of Strategic Air Command January – June 1968*, SAC Historical Study No. 112, volume 1, 89-92, 95.

[155] Strategic Air Command, *History of Strategic Air Command FY 1969*, SAC Historical Study No. 116, volume 1, 122-124.

[156] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 115.

[157] "Satellite Basing," memorandum of 27 December 1968, in *History of Strategic Air Command FY 1969*, volume 10.

[158] "Staff Visit Satellite Base Test Being Conducted at Homestead AFB, Florida," memorandum of 4 March 1969, in *ibid.*

[159] Patience Elizabeth Patterson, David P. Staley, and Katherine J. Roxlau: *A Baseline Inventory of Cold War Material Culture at Homestead Air Force Base*, volume II-11, and, *A Baseline Inventory of Cold War Material Culture at MacDill Air Force Base*, volume II-17, in *A Systemic Study of Air Combat Command Cold War Material Culture* (Albuquerque: Mariah Associates, Inc., for Air Combat Command, June and May 1997).

[160] Available progress reports include those the first six months of 1969. Sequencing indicates that the first report dated to December 1968, with end date undetermined. Strategic Air Command, *Satellite Basing Progress Report*, numbers 2, 3, 4, 6, February, March, April, and June 1969, in *ibid.* Over this six-month period SAC listed 27 Air Force bases, one Air Force base previously transferred to the Army (Hunter), six Naval Air Stations and one Marine Corps Air Station, as intended candidates for satellite alert. The list is partial, with Kelly Air Force Base, Campbell Air Force Station, Gray Air Force Station, Patuxent Naval Air Station, Fallon Naval Air Station, Yuma Naval Air Station, and "Beaufort" listed in other SAC supporting documents of the same period. The Air Force, and former Air Force, bases each already possessed moleholes with the exceptions of Andrews, Edwards, Hill, Kelly, McClellan, McConnell, and Tinker. The nine or 10 Naval Air Stations, as well as the two Air Force stations, would also have required entirely new infrastructure. Campbell and Gray both abutted nuclear weapons storage areas.

[161] Strategic Air Command, *History of Strategic Air Command FY 1970*, SAC Historical Study No. 117, volume 1, 144-146.

[162] "Satellite Basing Status, FY 1971," July-December 1970 and January-June 1971, in Strategic Air Command, *History of Strategic Air Command FY 1971*, SAC Historical Study No. 119, volume 9.

[163] Drawings, civil engineering vault, Hill Air Force Base. Particularly: "Fort Campbell, Kentucky, Satellite Basing Complex Foundation Plan. Modified for Site Adaptation at Hill Air Force Base." AW 30-11-02. The Fort Campbell date is April 1970, while the Hill adaptation is July 1971.

[164] Drawings, civil engineering vault, Wright-Patterson Air Force Base.

[165] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1970*, 130.

[166] "Satellite Basing, FY 70 and FY 71 MCP, Unnumbered Design Instruction," memorandum from the Director of Civil Engineering, Headquarters United States Air Force, 15 January 1971, in Air Force Logistics Command, *History of Ogden Air Materiel Area FY 1973*, volume 2.

[167] "Hill AFB Named One of Six SAC Satellite 'Alert' Bases,' *Hill Top Times*, 23 April 1971.

[168] "Tab B-1 Scope," 15 December 1970, in *History of Ogden Air Materiel Area FY 1973*, volume 2; drawings, civil engineering vault, Hill Air Force Base.

[169] Strategic Air Command, *History of the 456th Bombardment Wing (Heavy) April – September 1972*, 51-55.

[170] Strategic Air Command: *History of the 456th Bombardment Wing (Heavy) October – December 1972*; *History of the 456th Bombardment Wing (Heavy) April – June 1973*; and, *History of the 456th Bombardment Wing (Heavy) October – December 1973*, each volume 1.
[171] Strategic Air Command, *History of the 456th Bombardment Wing (Heavy) April – June 1974*, volume 1, photographs.
[172] Strategic Air Command, *History of the 456th Bombardment Wing (Heavy) January – March 1974*, volume 1, 51.
[173] *Ibid*, 58.
[174] Weitze: *Grand Forks Air Force Base: Inventory of Cold War Properties*, 1996; "Architectural Inventory and Evaluation of Cold War Properties at Minot AFB," in Maynard B. Cliff, Duane E. Peter, and William David White, *Minot Air Force Base Cultural Resources Management Plan* (Plano, Texas: Geo-Marine, Inc., for Air Combat Command, September 1996); and, R. Blake Roxlau, Karen Lewis, and Katherine J. Roxlau: *A Baseline Inventory of Cold War Material Culture at K.I. Sawyer Air Force Base*, volume II-13, and, *A Baseline Inventory of Cold War Material Culture at Minot Air Force Base*, volume II-19, of *A Systemic Study of Air Combat Command Cold War Materiel Culture*, 1997.
[175] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1972*, volume 3, part 1, 160.
[176] *History of the 456th Bombardment Wing (Heavy) April – June 1974*, volume 1, 48.
[177] "Satellite Base Working Group," document in *ibid*, volume 2.
[178] "Satellite Basing," memorandum of 17 September 1974, in Strategic Air Command, *History of Strategic Air Command FY 1975*, SAC Historical Study No. 153, volume 8.
[179] Strategic Air Command, *History of the 456th Bombardment Wing (Heavy) January – March 1975*, volume 1, 65.
[180] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 35-58.
[181] The author has addressed the subject of large phased-array radar in three preexisting studies. The discussion that follows is taken from these efforts, with endnoting only when a new source is introduced, refinements of earlier research are included, or, the original source is of key note to the reader. See Karen J. Weitze: *PAVE PAWS Beale Air Force Base: Historic Evaluation and Context* (Sacramento: KEA Environmental, Inc., for Air Combat Command, February 1999), and, Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 204-207, 298-305. The author has refined and expanded technical details for the PAVE PAWS and for the other large phased-array radars in the American network in *Historic American Engineering Record PAVE PAWS Radar Beale Air Force Base* (San Diego: EDAW, Inc., for Air Combat Command, as submitted to the National Park Service, Western Region, Department of the Interior, September 2002).
[182] Western Electric Company, *DEW East Completion Report*, 30 March 1962, 34-35.
[183] John Smith and David Byrd, *Forty Years of Research and Development at Griffiss Air Force Base June 1951 – June 1991*, R:-TR-92-45 In-House Report (Griffiss Air Force Base: Air Force Research Laboratory History Office, ca.1992).
[184] *Ibid.*
[185] Office of the Secretary of the Air Force, *United States Air Force Spacetrack*, booklet of July 1964; *Dedication National Space Surveillance Control Center*, 9 February 1960, foldout announcement.
[186] *United States Air Force Spacetrack*, 1964.
[187] Smith and Byrd, *Forty Years of Research and Development at Griffiss Air Force Base*, ca.1996.
[188] J. Emory Reed, "The AN/FPS-85 Radar System," *Proceedings of the IEEE [Institute of Electrical and Electronics Engineers]* 57, 3 (March 1969): 324-335; and, J.L. Allen, "Array Radars: A Survey of their Potential and their Limitations," *The Microwave Journal* 5, 5 (May 1962): 67-79, including a photograph of the ESAR.
[189] Mandy Whorton, *Deter and Defend: The History of the Development and Operation of the PAVE PAWS Radar* Network, Draft (Lakewood, Colorado: Argonne National Laboratory, August 2000), 25, 31.
[190] Summary discussion here is derived from Dena S. Komporlides, Christopher O. Hurst, Linda Auten, Cary D. Cotterman, and Susan L. Bupp, *Historical Overview of the National Advisory Committee for Aeronautics (NACA) and the National Aeronautics and Space Administration (NASA) at Edwards Air Force Base, California* (San Bernardino, California: Tetra Tech, Inc., for Air Force Materiel Command, February 1996).
[191] The discussion included here is drawn from a well-detailed analysis by the AFMC historian at Hanscom Air Force Base. See: Ruth Liebowitz, *Air Force Geophysics: Contributions to Defense and to the Nation, 1945-*

1995, PL-TR-97-2034, Special Report No. 280 (Hanscom Air Force Base: Geophysics Directorate, 8 April 1997).
[192] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 168-171, 255-258.
[193] *Ibid*, 207.
[194] Again, an excellent existing short study written within an AFMC history office serves as the basis for discussion of NASA and Air Force program relations for the Air Force Ballistic Missile Office and its follow-ons. See: Timothy C. Hanley and Harry N. Waldron, *Historical Overview Space & Missile Systems Center 1954-1995* (Los Angeles Air Force Base: Space and Missiles Systems Center History Office, June 1997). AFMC first published the study in April 1996, reprinting it with changes in the 1997 version.
[195] *Ibid*, 1.
[196] Two studies broadly discuss achievements and contributions by the USAFSAM at Brooks toward the NASA man-in-space program. See: Heather Puckett and Janet Ostashay, *Historic Building Inventory and Evaluation of Cold War-Era Buildings at Brooks Air Force Base* (Colton and Santa Monica, California: Earth Tech, Inc., and Planning Consultants Research, for the Air Force Center for Environmental Excellence, October 1998), and, Andrea Urbas and Paige Peyton, *Brooks Air Force Base, Texas: Man-in-Space Era Historic Building Inventory and Evaluation (Draft)* (Colton, California: Earth Tech, Inc., for the Air Force Center for Environmental Excellence, February 2001).
[197] James F. Aldridge, Dean C. Kallander, Paul C. Ferguson, Diana G. Cornelisse, Laura N. Romesburg, and Henry M. Narducci, *Against the Wind: 90 Years of Flight Test in the Miami Valley* (Wright-Patterson Air Force Base: Aeronautical Systems Center History Office, 1994), 54-57.
[198] *Ibid*, 66-83, 141.

Summary and Conclusions

Command Lineage, Scientific Achievements, and Major Tenant Missions functions as a broad overview of the historic development for the commands that led to Air Force Materiel Command in mid-1992, and is Volume I of the three-volume compendium *Keeping the Edge: Air Force Materiel Command Cold War Context (1945-1991).* The 45-year period of the Cold War offers the backdrop for the study. This volume provides a factual framework of command lineage, and includes many references to logistics depots and research centers either no longer within Air Force Materiel Command, or in some cases, no longer active Air Force installations. The volume also looks more closely at a few selected examples of major scientific achievements accomplished within Air Materiel Command during the late 1940s and Air Research and Development Command (ARDC) in the early 1950s. For this analysis, Part III of Volume I additionally examines the phenomenon of Project Paperclip and its impact on ARDC. The final section of the volume reviews several major tenant missions that occurred on multiple Air Force installations where the predecessors of Air Force Materiel Command were base hosts.

Cultural resource managers at active Air Force Materiel Command installations are encouraged to use *Command Lineage, Scientific Achievements, and Major Tenant Missions* as a companion to Volume II, *Installations and Facilities*, to support the inventory and National Register of Historic Places evaluation of Cold War properties. Volume III of *Keeping the Edge* gives all readers and researchers an index to the information in Volumes I and II. The index should enable individuals at specific installations to search the volumes for details particular to their installation, and should allow them to link to other command installations where their base sustained a presence. The author also hopes that *Command Lineage, Scientific Achievements, and Major Tenant Missions* will encourage future research within the Air Force history community and among architectural-engineering historians at large.

Suggested topics for continued research and evaluation are many. Based upon the documents and files analyzed for this study, and upon the review of the physical landscapes across the Air Force Materiel Command installations, the author offers the following ideas:

- a closer examination of the active installations that contributed to Air Materiel Command and ARDC during the early Cold War, and subsequently became installations operating under other Air Force commands (such as Fairchild, Holloman, and Patrick): the role of these installations in command history is not as fully addressed herein as the roles of today's bases;
- a parallel examination of the closed installations that contributed to the evolution of the command during the early Cold War (such as Brookley Air Force Base Alabama; Clinton County Air Force Base in Ohio; Norton Air Force Base in California; Olmsted Air Force Base in Pennsylvania; and, the Watson Laboratories in New Jersey): the history of these bases is also less thoroughly discussed in this study;
- a closer look at the depot system across Air Materiel Command and Air Force Logistics Command (AFLC), including many closed facilities;
- a delineation of the full Air Force Plant structure during the Cold War, with an emphasis on the decade of the 1950s: again, many of these plants closed as time went forward, with their lineage in this study not as precise as a more detailed review of plant records would allow (this kind of history would offer a framework for questions focused on industrial cleanup and possible litigation);
- an analysis of the corporate test sites supporting research for ARDC and Air Force Systems Command (AFSC): these test sites often included major prototype infrastructure and equipment, with their records an invaluable complement to those held within the command;

- a study of the most active architectural-engineering firms working for the command over time, with attempts made to contact successor firms that exist today: this type of history would bring to light further information about the truly unusual level of architectural-engineering talent that designed for Air Materiel Command and ARDC;
- a history of Air Materiel Command / ARDC's and AFSC / AFLC's involvement in the development of engineering and design expertise for protective, and subsequently hardened, construction during the Cold War;
- an examination of the command's role in the advancement of biological and chemical weapons, including the design and engineering of structures associated with such weapons; and,
- a careful compendium of Air Materiel Command and ARDC's involvement in personnel recruitment under Project Paperclip and its two follow-ons of the early and middle 1950s: these records are scattered and should be gathered together in a single analysis to support primary source documents that exist in the collections of the command.

Many other future studies are certainly possible, but these are the ones that the records suggest would be fruitful in their yield and valuable to Air Force Materiel Command. At the installation level, other projects (including inventory, cataloguing and preservation of drawings, and single-structure analysis) are likely.

Bibliography

The bibliography is organized in the references-cited format commonly found in government documents, but is focused on pertinent Air Force and Army literature. It is intended to facilitate further research as a stand-alone tool, and to encourage Air Force cultural resource managers and military historians to retrieve information from multiple archival collections. First sources provided below are general military, and real property, in character. Second sources are Air Force and Army Air Forces in type, and are substantially archived at the Air Force Historical Research Agency, Maxwell Air Force Base, Montgomery, Alabama, and at the National Archives II in suburban Washington, D.C. Cited authors vary from specific military historians to the command / tiered units responsible (without the historians called out by name). When given, individual Air Force historians are cited in brackets for their command or unit, and thus alphabetized by their Air Force affiliation rather than by surname. Final sources included here are those that are available at the installation level, concentrating on engineering drawings and oral interviews of past personnel. The bibliography also includes the references pertinent to the plates, where those items are not called out in endnotes. Not found in the bibliography are history and engineering references of non-military type, as well as articles from engineering journals, newspapers and broad histories, and internet postings. These items appear in their complete citations in the chapter endnotes.

Particularly important to any analysis of Air Force historic real property are documents held at the Air Force Historical Research Agency at Maxwell Air Force Base. The Historical Research Agency serves as the primary repository for all Air Force records below the policy level and maintains truly excellent holdings. Bibliographic entries below include numeric coding specific to the Agency, to make any requests for the documents as efficient as possible. Researchers need to add the associated dates for each code—typically those included in the document title. Dates are given within the reference code where any possibility of confusion remains. If a volume number is included in the coding, this typically indicates a narrative (usually as volume 1) and appendices (volumes 2 forward). Sometimes, however, unusual situations occur. For the histories of Air Force civil engineering at the Headquarters level, such is the case. For these entries, volume number in the coding refers to the specific sequencing of the civil engineering (earlier, installations) directorate among that for other directorates (such as operations) within the volume series. One other confusing situation occurs with regards to volume numbering for documents at the Air Force Historical Research Agency. For some documents, the individual item has an alternate title and is a volume in another series. In these cases, when useful, the volume number of the series is included after the title, while the volume number given with the K coding usually refers to distinctions between narrative and appendices. The histories for the Cambridge Research Laboratories / Center are an excellent example of the "double" volume numbering. Both Air Defense Command and Strategic Air Command also have multiple special studies series, with separate volume numbering. When no volume number is given in the K coding, this typically indicates that there is only one volume. If appended documents exist in these instances, they are bound with the narrative history.

The system used at the Air Force Historical Research Agency is particularly critical to relocating documents. For Air Force Historical Research Agency sources, a researcher is encouraged to request materials by their "K" number. Without this information, search time can be lengthened considerably—especially in any request for specific test reports, memoranda, and letters. The K system is divided into sources before and after mid-1950, with those of July 1950 forward recorded with the "K," while those before this date have only a numeric sequence (K280.10-48 versus 280.10-47, for example). The system is generally consistent, but not absolute due to the sheer size of the Air Force Historical Research Agency collections.

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